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1.0 INTRODUCTION

This document is prepared in fulfillment of the requirements of paragraph B(1.1.1.1.3.1) of the Statement of Work, System 620A Dyna Soar (Step I), Exhibit 620A-61-28, dated 1 September 1961. The purpose of this document is to present the current status of the Dyna Soar glider's stability and control aerodynamic characteristics.

The contents include static and rotary force and moment coefficients, trim characteristics, control surface hinge moments, limited effects of flexibility and thermal deformation and aerodynamic performance characteristics. Limited data is also presented on the glider and abort vehicle in the presence of the air carrier.

The purpose of this document has also been broadened to the extent that it becomes the primary vehicle of aerodynamic data and flight constraints for flight control subsystem design and simulator design. New data sections including performance, constraints due to aerodynamic heating and loads, and glider aerodynamic characteristics in the presence of the air carrier for drop tests have been added to fulfill the documents broader objectives.

Significant changes have been made in the glider and abort vehicle aerodynamic configuration to warrent a complete revision of this document. These changes are described in detail in Section 3 "Configuration Description". Time has not permitted complete wind tunnel test verification over the flight regime of the latest configuration.

Periodic revisions to this document are scheduled for the future. Additions and revisions to the data presented will be made at these times pending the results of additional wind tunnel data and analysis.

12-20-61

2.0 REFERENCES

1. Boeing Document D2-6444, "IBM 704 Compressible Laminar Boundary Layer Program # 1" by K. Halvorson and C. Cassmeyer.

2. Boeing Aero-Performance CS #28, "Results from Digital Programs Solving the Laminar Compressible Boundary Layer" 24 August 1960.

3. NASA TMX-287, Theoretical Stability Derivatives for the X-15 Research Airplane at Supersonic and Hypersonic Speeds Including a Comparison with Wind Tunnel Results, by Walker and Wolowicz, August 1960.

4. C110-10440, Dyna-Soar I Configuration Evaluation Wind Tunnel Test Report Series II, Bell Aircraft Corporation, May 1959.

5. Donovan and Lawrence, "Aerodynamic Components of Aircraft at High Speeds," High Speed Aerodynamics and Propulsion Series, Vol. 7, Princeton University Press, 1957, pp. 150 to 172.

6. Boeing Document D3-3712, "Aerodynamic Analysis Report of B-52/ Dyna-Soar Glider Wind Tunnel Test," BTWT 647, October 24, 1961.

7. Appropriate Wind Tunnel Tests

BTWT 634	D2-8225, Data Report, Boeing Transonic Wind Tunnel Test Number 634 Low Speed Longitudinal and Lateral Stability Tests of AD544I-1 A 0.15 Scale Model of the Dyna-Soar Step I Glide Vehicle.
BTWT 655	D2-80298 Data Report, 655 Transonic Speed Test of the Dyna-Soar Glider
BTWT 672	D2-80494 Unreleased Document
BTWT 680	No document number or title at this date.
BTWT 682	No document number or title at this date.
BTWT 685	No document number or title at this date.
BSWT 105	D2-80347 Unreleased
BSWT 113	D2-80407 Unreleased
BSWT 113B	D2-80492 Unreleased
BAC 18	D2-80006 Data Report AC Tunnel B Boeing Test No. 18 Hypersonic Stability and Performance Tests of AD540I-1 A .066 Scale Model of Dyna-Soar.
BAC 21	D2-80418 Unreleased document.

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3.0 CONFIGURATION DESCRIPTION

3.1 CONFIGURATION DESCRIPTION - GLIDER

A three view drawing of the model 844-2050 Revision D glider is presented in Figure 3.1 . The glider is shown in the cold shape or jig condition as would exist prior to re-entry. A photograph of an .067 scale model of this configuration is shown on Figure 3.2 .

Features significant to the stability and control characteristics are discussed in the following paragraphs.

The wing is essentially triangular in planform with a leading edge sweep angle of 72° 48'. The lower surface of the wing is a flat surface with a positive nose incidence of 3° occurring at Body Station 299.00. Thermal deformation will increase this nose bend up to approximately 4°. The clearance between the outboard edge of the elevon and the rudder actuator housing has taken the form of a tapered gap. This gap has been minimized to allow maximum longitudinal stability in the subsonic-transonic regime while still satisfying the thermal expansion requirements for clearance at hypersonic speeds.

The forebody nose contours have the greatest destabilizing effect in yaw. These contours are determined from aerodynamic considerations, structural, space, and visibility requirements. A ramp, commencing at Body Station 388.5 and expanding to a thickness of 12.0 inches at the aft end of the body, has been added to the top surface of the body. This ramp produces a positive C_{m_0} shift and a reduction in elevon hinge moments at low supersonic speeds. This ramp has also a favorable effect on transonic directional stability. The APU exhaust ports are relocated on the ramp.

A probable critical temperature problem innate to the previous cab-heatshield design has required a modification of these parts. The changes have essentially raised the top portion of the heatshield and replaced the radial fairing between the top and front of the cab with a flat surface.

The speed brake has been deleted. Studies have revealed that the simultaneous outboard deflection of the rudders will provide the necessary braking effect.

The vertical tail must provide an efficient lifting surface and yet be of minimum dimensions for weight, drag, structural, and thermal requirements. The existing planform of 844-2050 D glider has an area of 31.3 ft.^{2} per side with a 55° leading edge sweep. The tail is located as far aft of the center of gravity as structurally possible for static directional stability and on the wing tips to minimize wing and body interference. The tails are canted inboard

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3.1 CONFIGURATION DESCRIPTION - GLIDER (Cont'd)

at an angle of 9° 56' to give increased directional stability through small angles of sideslip at hypersonic speeds.

A significant change in the vertical tail for this configuration is the increased thickness of 8.0 inches. The leading edge of the fin is made up of a 3.0 inch radius which satisfies the heating design requirement, and a flat surface required to complete the 8.0 inch thickness. However, this "radius-flat" leading edge fairs into a 4.00 inch radius leading edge at the rudder.

Physical dimensions of the actuators have required the enlargement of the rudder actuator housings. Other modifications, primarily required for heating and clearance requirements, are the 4.0 inch radius on the upper fin at the rudder hinge line and a 20.0 inch radius on the lower rudder at the hinge line.

The rudders will be trailed inboard 6° 0' from the faired position to reduce hinge moments for the subsonic through low supersonic speed range. To obtain the directional stability required at higher speeds, the rudders will be in the faired position as shown in Figure 3.1 . The position of the rudder trail will be controlled by the pilot. The rudders will be deflected together and will be capable of 35° outboard and 12° inboard deflection.

Aerodynamic control about the pitch and roll axis is provided by the trailing edge elevons. The elevon planform has been influenced by several design considerations. The inboard edge is determined by structural and space requirements. The sweep and radius of the outboard edge and leading edge are determined by aerothermodynamic limits and by the rudder actuator housing. The trailing edge and sweep has been determined by planform studies of sweep angle for best stability. The elevons have the hinge lines normal to the plane of symmetry of the vehicle. The trailing edges are swept 10° 28'. The outboards edges have been modified to obtain a minimum gap and to conform to the enlarged rudder actuator housing. These boundaries have produced a total elevon area of 46.0 ft.^{2} with a minus 10° 0' wedge cross section.

The elevons provide the glider with adequate pitch control to trim and maneuver the glider. The differential use of the elevons provides the necessary roll control. The elevons must also provide adequate control moments for augmentation as required by the Flight Control System. The deflections of the elevons are 55° up and 16° down at a deflection rate of 20°/sec. under no load.

The glider landing gears, equipped with uncooled all-skid surfaces, utilize the tricycle arrangement. All three struts and skids retract

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3.1 CONFIGURATION DESCRIPTION - GLIDER (Cont'd)

forward for storage. The gear is extended by a gas system with aerodynamic assist. The rate of extension is controlled by the snubbing action of the gas actuators. No sequencing of the gear is currently planned during extension.

The reaction control system used for control during orbital flight and for augmenting the aerodynamic control surfaces in the upper atmosphere are powered by a H_2 and O_2 fueled hot gas system. Pilot control inputs are accomplished through the sidestick controller when the stick deflection exceeds a predetermined dead band. These inputs operate on-off valves at the reaction nozzles. The reaction nozzles are located on the glider to give control about the three vehicle axes. The pitch up nozzles are atop the body and aft at Body Station 450.0. The pitch down nozzles are on the lower surface of the actuator housing at Body Station 473.67. The roll nozzles are on the upper surfaces of the wing at Body Station 355.3 and Buttock Line 72.0. The yaw nozzles are near the aft end of the body at Body Station 452.3 and Water Line 124.3.

A more detailed description of the configuration and systems is included in Reference Number .

3.2 THIRD STAGE CONFIGURATION

The glider and booster are integrated into an overall flight vehicle by means of a transition section which serves as the structural connection and aerodynamically smooth fairing between the booster and glider. The transition section general arrangement is shown in Figure 3.1 .

The glider abort and air launch system consists of the glider plus transition section which contains the acceleration rocket. To achieve additional control during abort, the thrust vector control of the acceleration rocket is used along with the aerodynamic controls.

The acceleration rocket is a solid propellant rocket with a propellant weight of 2200 pounds. The four nozzles are all hinged and located with centers on 45 diagonals in the rear view. They may be all used in pitch, yaw, roll or combinations required.

3.3. WEIGHTS AND MOMENTS OF INERTIA

The design weights and moments of inertia for the glider vehicle are presented below.

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3.3 WEIGHTS AND MOMENTS OF INERTIA

For the glider alone (transition section off):

Weight = 10000 lbs.
Principle moments of inertia about C.G.:

I_y = 19,229 slugs - ft^2 (pitch)
I_x = 4378 slugs - ft^2 (roll)
I_z = 22,103 slugs - ft^2 (yaw)

The nominal center of gravity for the glider alone is at Body Station 355.3 and Water Line 124. See Figure 3.1 .

For the 10000 lb. glider plus third stage, Figure 3.3 gives the moments of inertia, gross weight, and center of gravity from the beginning to the end of third stage burning.

3.4 AERODYNAMIC DATA AND REFERENCE CONSTANTS

Aerodynamic data in the document are presented on a fixed body axis system. The axis system is shown on Figure 3.4 . Definition of angle of attack and sideslip and the sign convention for the force and moment coefficients are also shown. The sign conventions for control deflections are shown on Figure 3.5 .

Reference constants and glider alone center of gravity location are shown on Figure 3.6 . Some significant aerodynamic configuration constants are also presented.

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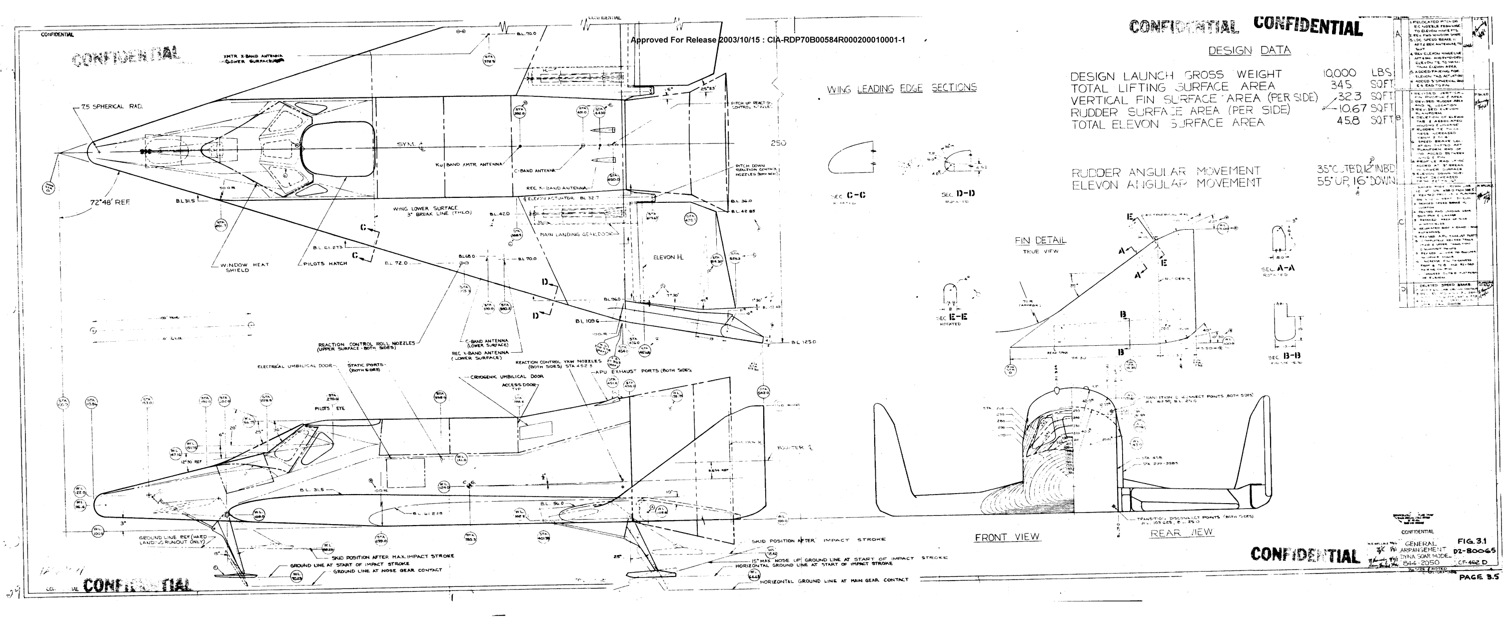

GENERAL ARRANGEMENT DYNA SOAR MODEL 844-2050

FIG. 3.1

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CF-462 D

2A 73512

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FIG. 3.2
D2-80065
PAGE 3.6

DATA IS DERIVED FROM PREVIOUS MASS DATA CONSIDERING ONLY THE REDUCTION OF 1000 LBS PROPELLANT. CHANGES DUE TO ALTERATIONS IN TRANSITION AND ROCKET INERTS ARE NOT CONSIDERED.

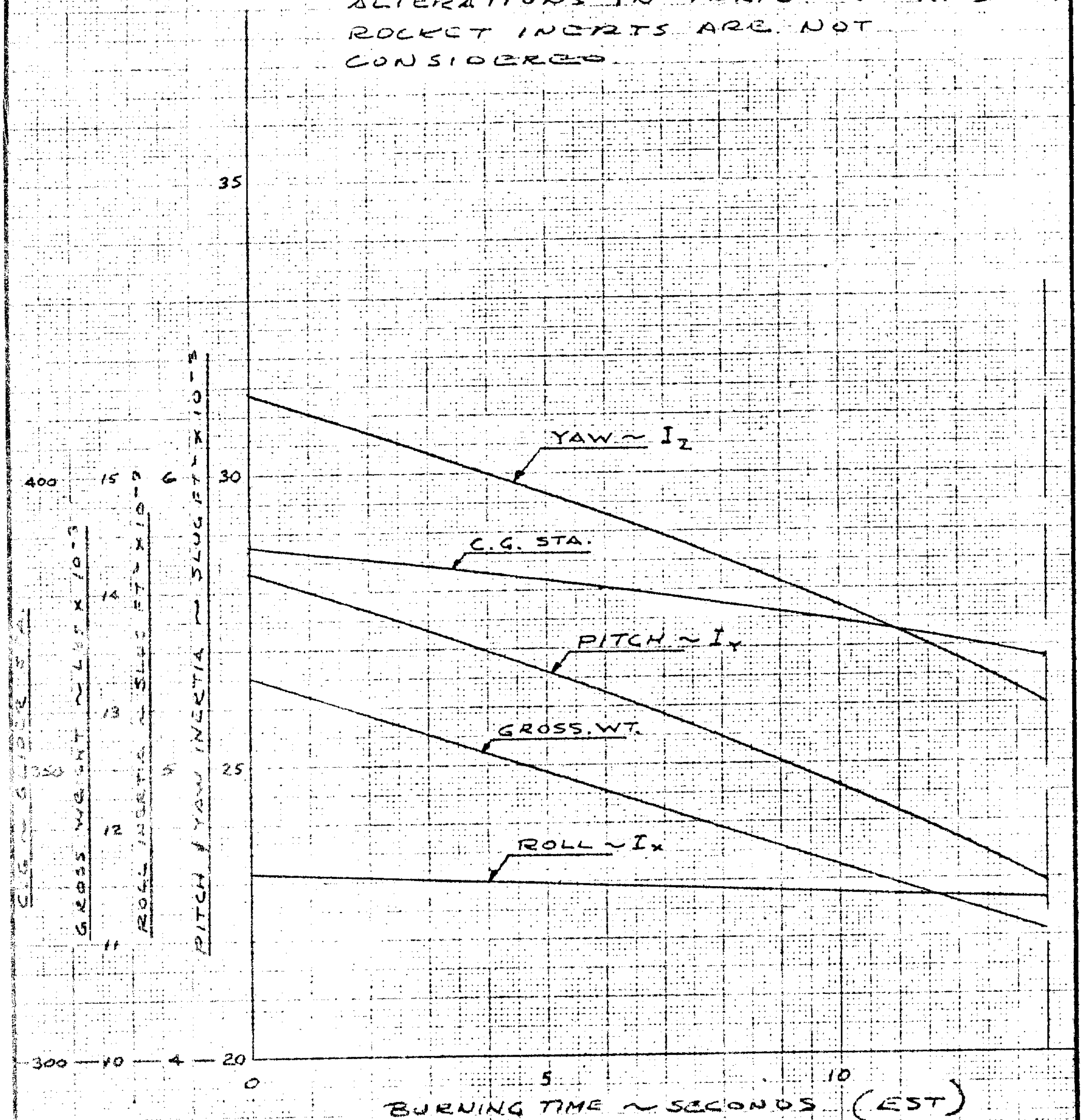

FIG. 33

CALC	bwR	1/24/61	REVISED	DATE	EST. MASS DATA GLIDER + 3RD STAGE (2200 # PROPELLANT)	DS-1 2050
CHECK						D2-8006S
APR					BOEING AIRPLANE COMPANY	PAGE 37
APR						

U3 4013 8000 (WAS BAC 461 C-R4)

K+E ALBANENE TRACING PAPER

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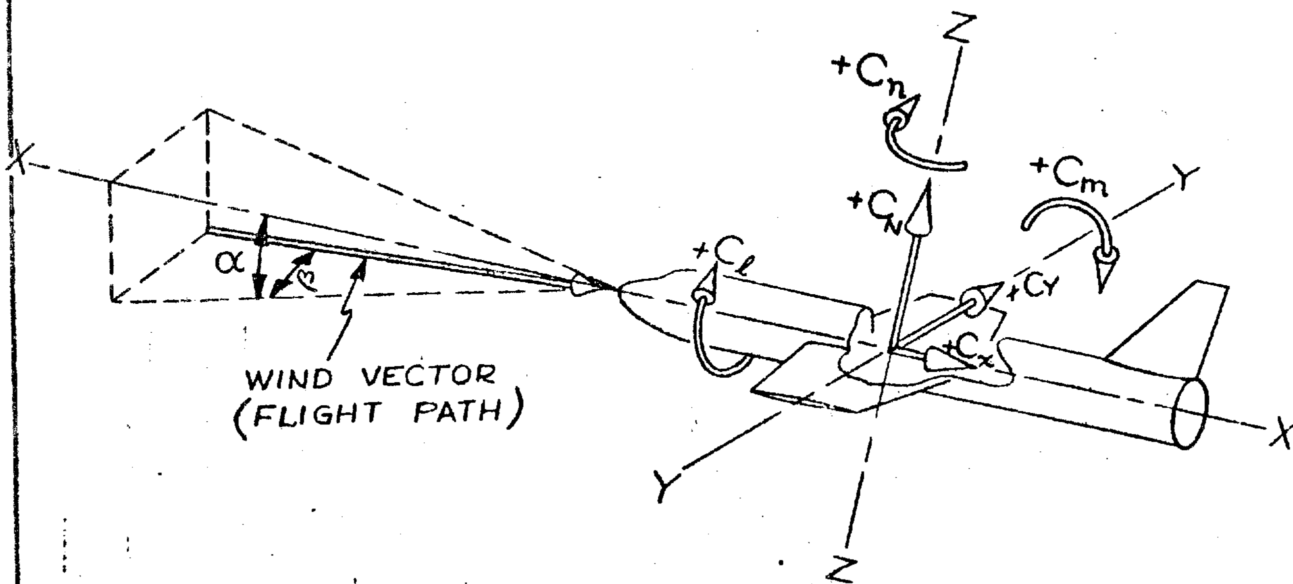

NOTES:

1.) THE MUTUALLY PERPENDICULAR X, Y, AND Z AXES ARE FIXED ON THE AIRPLANE, REGARDLESS OF FLIGHT ATTITUDE.

2.) ANGLE OF ATTACK IS MEASURED IN THE AIRPLANE PLANE OF SYMMETRY (X-Z PLANE), BETWEEN THE AIRPLANE X-AXIS AND THE PROJECTION OF THE WIND VECTOR INTO THE X-Z PLANE.

3.) ANGLE OF SIDESLIP IS MEASURED IN OR PARALLEL TO THE PLANE DEFINED BY THE AIRPLANE Y-AXIS AND THE WIND VECTOR, BETWEEN THE WIND VECTOR AND THE PROJECTION OF THE AIRPLANE X-AXIS INTO THE ABOVE-DEFINED PLANE.

4.) FOR THE DYNA SOAR 844-2050 CONFIGURATION, THE X-Y PLANE IS PARALLEL TO THE FLAT, AFT PART OF THE WING UNDERSURFACE.

FIG. 3.4

			REVISED	DATE		
CALC					BODY AXIS SYSTEM NOMENCLATURE ~ COMBINED ANGLE OF ATTACK & SIDESLIP	844-2050D
CHECK			12-2-61			D2-80065
APR					BOEING AIRPLANE COMPANY	PAGE 3.8
APR						
DWN	M. CARTER	12-28-0				

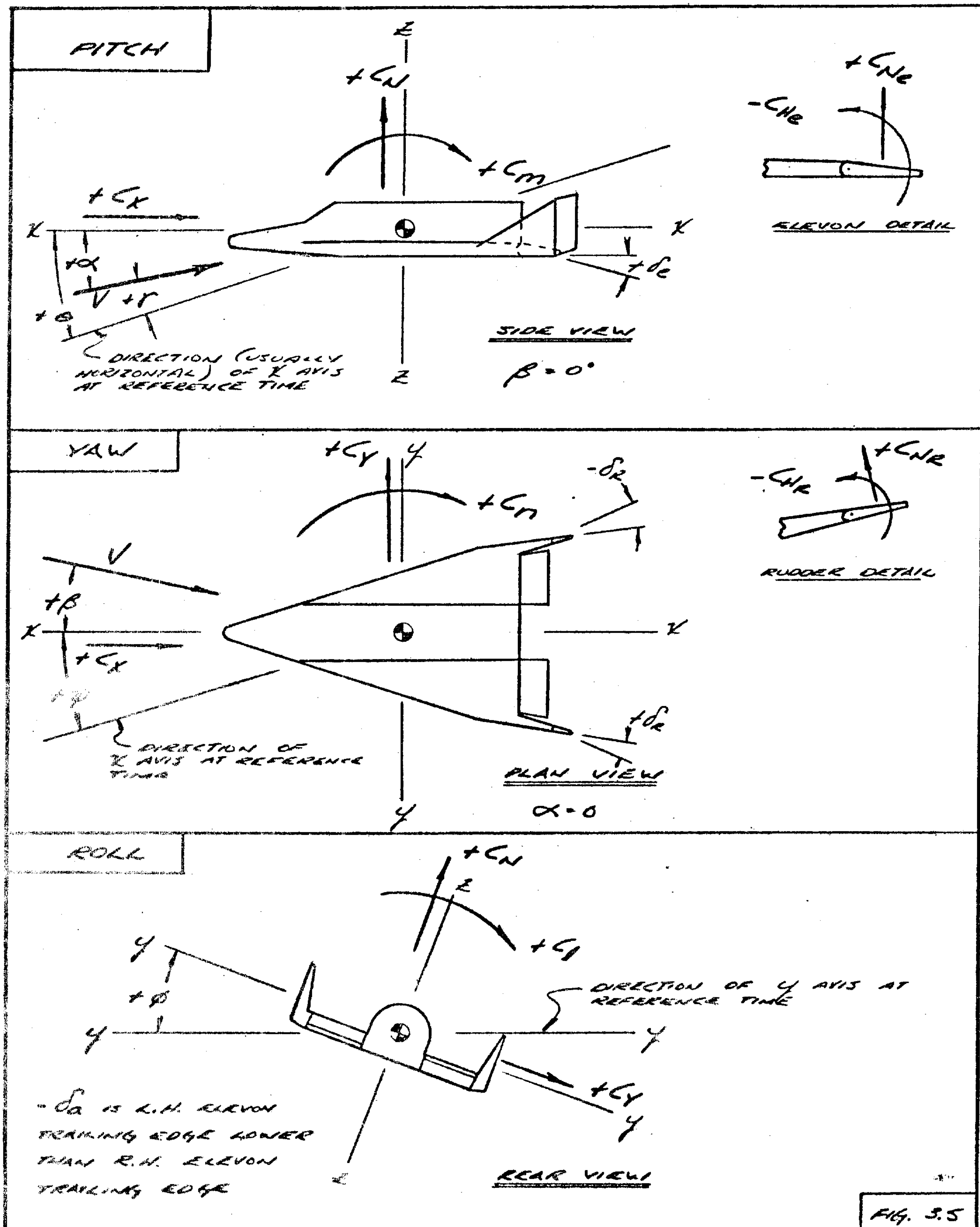

FIG. 3.5

CALC			REVISED	DATE	BODY AXIS SYSTEM NOMENCLATURE	2050 0
CHECK			Lawson	12.8.?		
APR				12.20.?		D2-80065
APR						
Onl	Carter	12.27.?				PAGE 3.9

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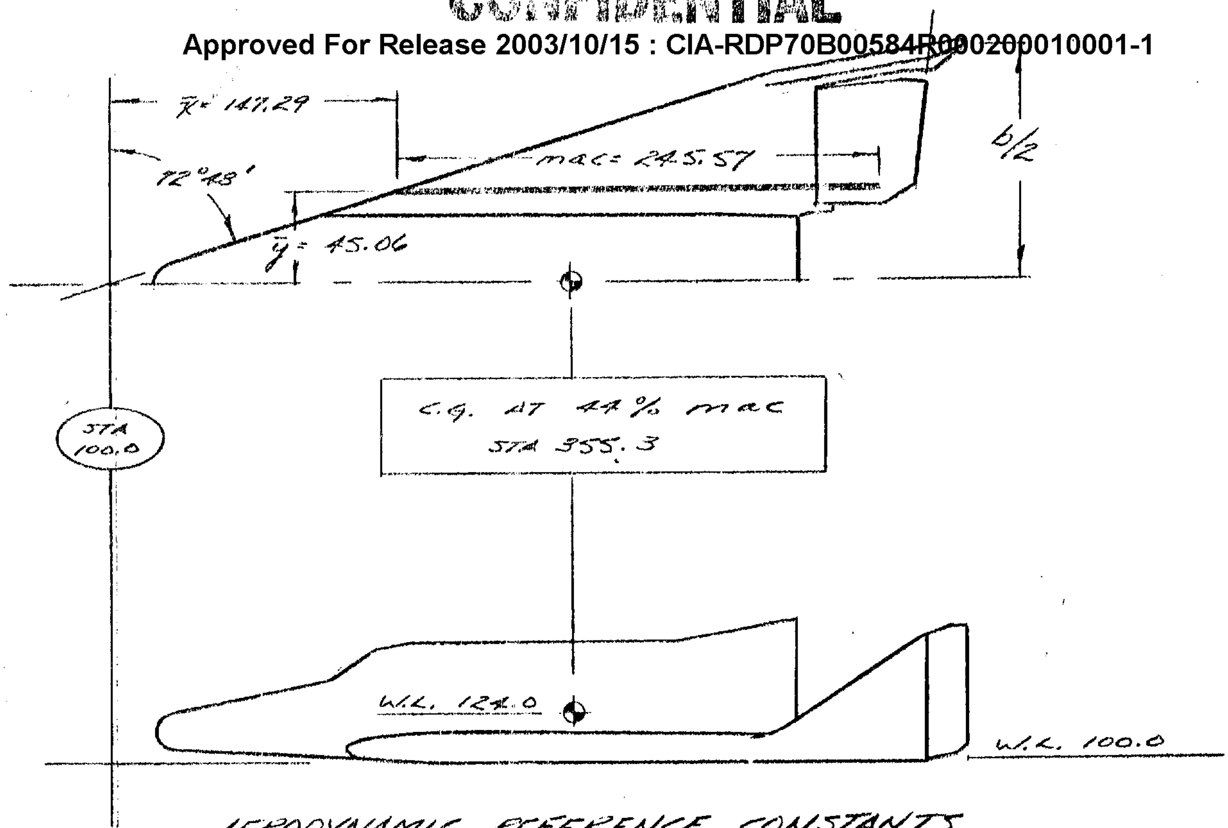
BAC 1017-R5



AERODYNAMIC REFERENCE CONSTANTS

S_W, WING AREA	345 FT.^{2}
mac, MEAN AERODYNAMIC CHORD	245.57 IN.
b, SPAN	245.48 IN.
AR, ASPECT RATIO	1.21

VERTICAL TAIL

$S_{V.T.}$, TAIL AREA (PER SIDE)	31.3 FT.^{2}
$S_{V.T.}/S_W$, BOTH SIDES	0.182
$l_{V.T.}$	148.88 IN.
$\bar{V}_{V.T.} = \frac{S_{V.T.}\, l_{V.T.}}{S_W\, b}$, BOTH SIDES	0.110

RUDDER

S_R, RUDDER AREA (PER SIDE)	10.6 FT.^{2}
S_R/S_W, (BOTH RUDDERS)	0.061
l_R	175.5 IN.
$\bar{V}_R = \frac{S_R\, l_R}{S_W\, b}$, (BOTH RUDDERS)	0.044
$2M_a$	245 IN-FT.^{2}

ELEVON

S_e, TOTAL ELEVON AREA	46.0 FT.^{2}
S_e/S_W, TOTAL AREA	0.133
l_e	138.3 IN.
$\bar{V}_e = \frac{S_e\, l_e}{S_W\, \bar{c}}$, TOTAL AREA	0.075
$2M_a$	1195 IN-FT.^{2}

CALC	Smith	12-15-1	REVISED	DATE	AERODYNAMIC REFERENCE CONSTANTS	FIG. 3.6
CHECK				12-23		844-2050 D
APR						D2-80065
APR					BOEING AIRPLANE COMPANY	PAGE 3.10

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4.0 DEFINITION OF SYMBOLS

a.c.	aerodynamic center
A/F	airframe
b	wing span
B.L.	buttock line
B.S.	body station
c.g., C.G.	center of gravity
C_D	drag coefficient
δ_{R_L}	left rudder deflection
δ_{R_R}	right rudder deflection
W_p	weight of acceleration rocket propellant
W	glider weight
q, $\bar{q}$, Q	dynamic pressure
M	Mach number
I_x	moment of inertia about x axis
I_y	moment of inertia about y axis
I_z	moment of inertia about z axis
C_{H_β}	$\partial C_H / \partial \beta$
$C_{H_{\delta_e}}$	$\partial C_H / \partial \delta_e$
C_{H_α}	$\partial C_H / \partial \alpha$
C_{H_o}	hinge moment coefficient at $\alpha = 0°$, $\delta_e = 0°$, $\delta_R = 0°$, $\beta = 0°$
C_{H_e}, C_{h_e}	elevon hinge moment coefficient
C_{H_R}, C_{h_r}	rudder hinge moment coefficient
g, G	acceleration due to gravity
n, g	load factor = $\frac{\text{lift}}{\text{weight}}$
V	resultant wind velocity or free stream velocity
W.L.	water line

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$\bar{c}$ or m.a.c.	mean aerodynamic chord
C_L	lift coefficient, $\frac{L}{q S_w}$
C_m	pitching moment coefficient, $\frac{M}{q S_w \bar{c}}$
C_{m_o}	pitching moment coefficient at zero lift
C_{m_q}	$= \partial C_m / \partial(q\bar{c}/2V)$
C_{m_α}	$= \partial C_m / \partial \alpha$
$C_{m_{\dot{\alpha}}}$	$= \partial C_m / \partial(\dot{\alpha}\bar{c}/2V)$
$C_{m_{\delta a}}$	$= \partial C_m / \partial \delta a$
$C_{m_{\delta e}}$	$= \partial C_m / \partial \delta e$
C_n	yawing moment coefficient, $\frac{N}{q S_w b}$
C_{n_p}	$= \partial C_n / \partial(pb/2V)$
C_{n_r}	$= \partial C_n / \partial(rb/2V)$
$C_{n_{\delta a}}$	$= \partial C_n / \partial \delta a$
$C_{n_{\delta R}}$	$= \partial C_n / \partial \delta_R$
C_{n_β}	$= \partial C_n / \partial \beta$
$C_{n_{\dot{\beta}}}$	$= \partial C_n / \partial(\dot{\beta}b/2V)$
C_N	normal force coefficient, $\frac{N}{q S_w}$
C_{N_α}	$= \partial C_N / \partial \alpha$
$C_{N_{\dot{\alpha}}}$	$= \partial C_N / \partial(\dot{\alpha}\bar{c}/2V)$
$C_{N_{\delta a}}$	$= \partial C_N / \partial \delta a$
$C_{N_{\delta e}}$	$= \partial C_N / \partial \delta e$
C_{N_q}	$= \partial C_N / \partial(q\bar{c}/2V)$
C_x	axial force coefficient, $\frac{X}{q S_w}$
C_Y	side force coefficient, $Y/q S_w$
C_{Y_β}	$= \partial C_Y / \partial \beta$
$C_{Y_{\dot{\beta}}}$	$\partial C_Y / \partial(\dot{\beta}b/2V)$

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S_e or S_E	elevon area
S_r or S_R	rudder area
S_t	wing tip extension area
S_w	wing area
V	velocity
X	force along X (roll) axis
Y	force along Y (pitch) axis
α	angle of attack
α_{OL}	angle of attack at zero lift
β	angle of sideslip
δ_a	aileron deflection angle = $\frac{\delta_{e_R} - \delta_{e_L}}{2}$
δ_{e_L}	left elevon deflection angle
δ_{e_R}	right elevon deflection angle
δ_e OR δ_E	elevon deflection angle, elevons deflecting together
δ_R	rudder deflection angle
Θ	pitch angle
ϕ	roll angle
ψ	yaw angle
λ	wing taper ratio $\frac{ct}{cr}$
C_ℓ	rolling moment coefficient, $\frac{\ell}{q S_w b}$
C_{ℓ_p}	$= \partial C_\ell / \partial (pb/2V)$
C_{ℓ_r}	$= \partial C_\ell / \partial (rb/2V)$
C_{ℓ_β}	$= \partial C_\ell / \partial \beta$
$C_{\ell_{\dot\beta}}$	$= \partial C_\ell / \partial (\dot\beta b/2V)$
$C_{\ell_{\delta a}}$	$= \partial C_\ell / \partial \delta_a$
$C_{\ell_{\delta R}}$	$= \partial C_\ell / \partial \delta_R$

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$C_{Y\delta a}$	=	$\partial C_Y / \partial \delta_a$
$C_{Y\delta r}$	=	$\partial C_Y / \partial \delta_R$
C_{Yp}	=	$\partial C_Y / \partial (pb/2V)$
C_{Yr}	=	$\partial C_Y / \partial (rb/2V)$
C_h		hinge moment coefficient, $\frac{HM}{q S_e C_e}$
$C_{h\alpha}$	=	$\partial C_h / \partial \alpha$
$C_{h\delta e}$	=	$\partial C_h / \partial \delta_e$
$M_a = \int y\, da$		Moment area of the control surface aft of the hinge line.

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5.0 CONSTRAINTS DUE TO AERODYNAMIC HEATING AND LOADS

5.1 INTRODUCTION

Various constraints are placed upon the glider and air vehicle performance by aerodynamic heating and/or loads. Generally, these constraints take the form of a lower limit in allowable altitude at a given velocity and vehicle attitude. Such limits may result from

(a) Temperature limit capability - a function only of aerodynamic heating rate, surface emissivity, maximum allowable temperature, and thermal storage. (The effect of thermal storage is very small for most Dyna-Soar conditions.)

(b) Combined temperature/load limit capability - same as (a) except allowable temperature depends on local pressure.

(c) Structural load factor capability.

(d) Panel flutter characteristics.

There are two general classes of limits: basic limits, which define the altitude-velocity-attitude region in which the vehicle can operate, and control surface limits, which primarily define the allowable control surface deflection limits at a given flight condition. Basic limits are given in Section 5.2 and control surface limits in Section 5.3.

5.2 BASIC LIMITS

Glider limits for zero control surface deflection are shown in Figures 5.1 through 5.3. Limits are applicable to three phases of flight, 1) boost, 2) reentry and 3) abort conditions after separation. As such, they define minimum allowable altitude for a given Mach number or velocity as a function of vehicle attitude.

Limits imposed during boost (Figure 5.1) have been evaluated under static conditions and define maximum structural load capability of the air vehicle for the Mach numbers indicated. During higher speed phases of boost, the glider limits given below must not be exceeded. Limits due to booster case heating are transient in nature, requiring evaluation for each specific trajectory, and consequently are not shown.

Limits imposed during reentry (Figure 5.2) are based on panel flutter characteristics and structural load factor capability at

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velocities from 1000 fps to 3000 fps. The limit is defined by combined temperature/load limit capability of the vehicle from a velocity of 4000 fps through 16,000 fps. Above 16,000 fps, steady state allowable temperatures define the limit which are a function only of aerodynamic heating surface emissivity and maximum allowable temperature.

There are no constraints imposed on the air vehicle at the initiation of abort except those limits imposed during normal boost. However, boost cannot be initiated in a manner that would cause the glider to penetrate the recovery ceiling or the basic reentry limits shown in Figure 5.2 and/or 5.3.

Limits of the glider and transition section after abort has been initiated and separation occured is shown in Figure 5.3. Structural capability is that limited by load factor, flutter and thermal considerations, whichever is the most restrictive.

5.3 CONTROL SURFACE LIMITS

Steady state control surface limits are given for unyawed flight in Figures 5.4 through 5.20 (elevons) and Figures 5.21 through 5.29 (rudders). Limits are shown in terms of minimum allowable altitude for given velocity, vehicle attitude for given velocity, vehicle attitude, and control surface deflection; conversely, they may be interpreted as maximum allowable control surface deflection for given flight condition and vehicle attitude.

Limits shown are based on steady state equilibrium skin temperatures only, and are determined by upper and lower elevon surfaces, respectively, for up and down elevon deflection, and by the rudder outboard surface. No reduction in temperature capability due to loads has been included, nor any allowance for thermal storage effects.

Upper elevon surface material characteristics are such that a certain amount of transient capability is provided; that is, the steady state up-elevon deflection limits may be exceeded for limited periods during transient maneuvers.

Little transient capability is provided by surface material characteristics of the lower elevon and outboard rudder surfaces. The effect of loads and transients will be included in future revisions.

Basic glider limit lines shown in Figure 5.2 are repeated as the lower envelope of the control surface lines of Figures 5.4 through 5.29. Also shown for comparison purposes are the glider limit altitudes based on maximum allowable temperature only, neglecting loads.

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Adjustments to rudder deflection limits for the effect of sideslip are made with the aid of Figures 5.30 through 5.33, in which the deflection limits including sideslip are presented as a function of zero-sideslip limits. As the effect of sideslip varies with angle of attack, plots are presented for α = 17.5, 30, 40, and 55°.

Effects of yaw on elevon deflection limits have not yet been determined, but are thought to be relatively small. They will be included in future revisions of this document.

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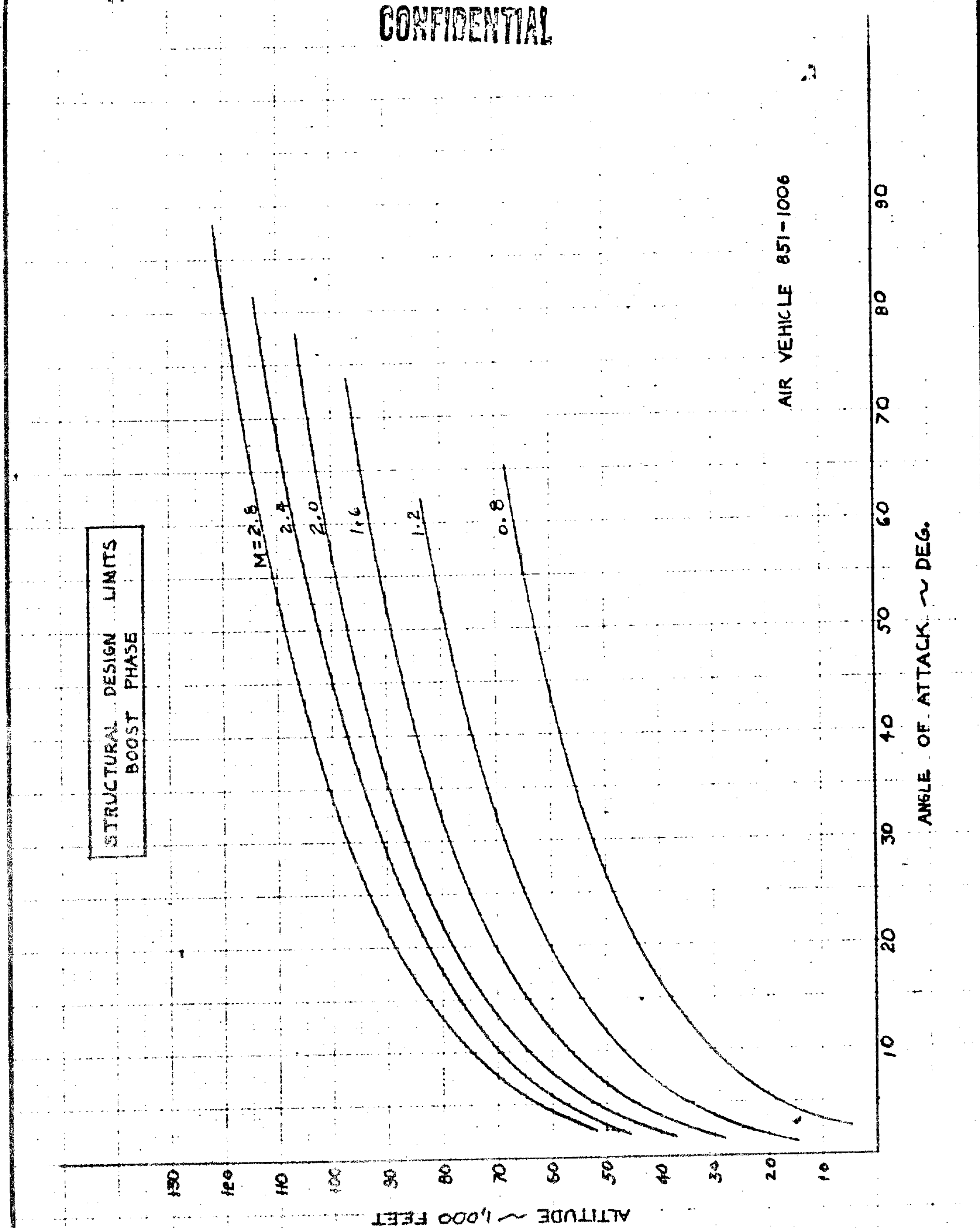

FIG. 5.1

CALC	M H		REVISED	DATE	STRUCTURAL DESIGN LIMITS BOOST PHASE	844-2050D
CHECK		12-…				D2-80065
APR						PAGE 5.4
APR					THE BOEING COMPANY	

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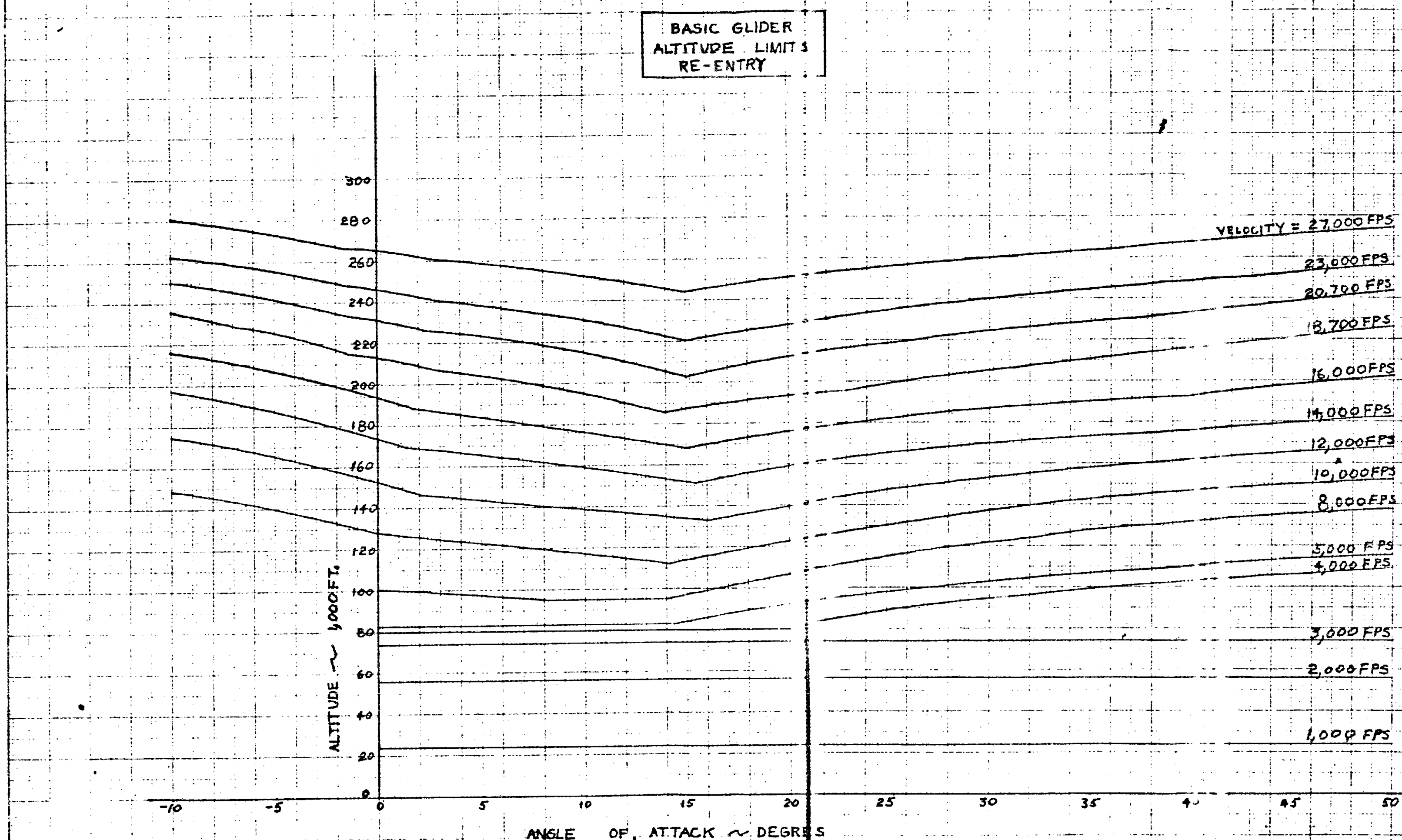

FIG. 5.2

CALC	H.K.		REVISED	DATE	BASIC GLIDER — TEMPERATURE AND TEMPERATURE / STRUCTURAL LOAD CAPABILITY: ALTITUDE LIMITS -	844-2050D
CHECK	ACT	12/16				D2-8006S
APPD						PAGE 5.5
APPD						

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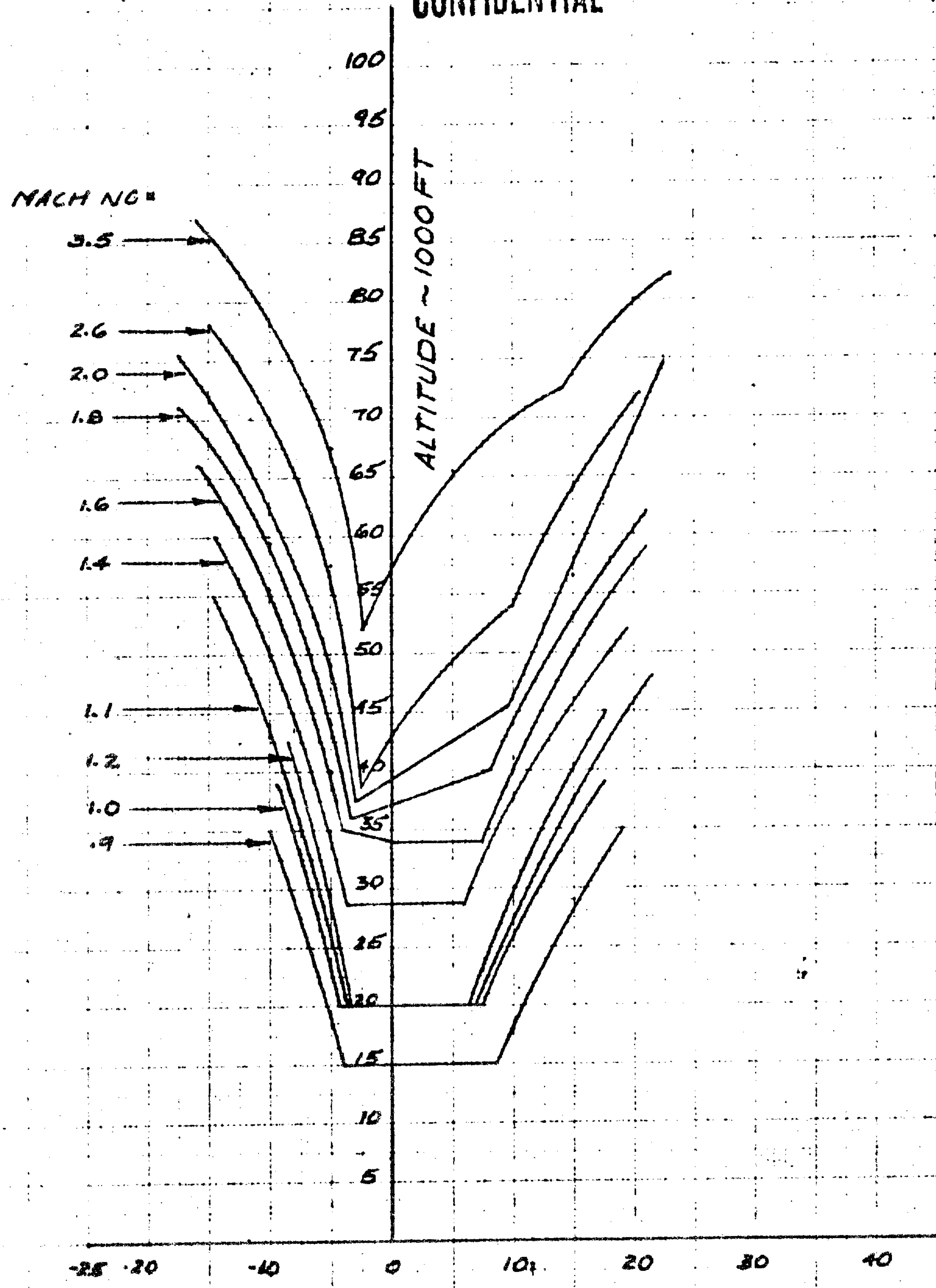

FIG. 5.3

CALC	D.E. BENNETT	12-15-61	REVISED	DATE	STRUCTURAL LIMIT LINES - GLIDER PLUS TRANSITION SECTION - ABORT CONDITION	844-2050 D
CHECK				12-20-61		D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 5.6

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CALC	D.E. BENNETT	12-12-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDE ELEVONS V= 6,000 FPS
CHECK	ACT	12-12-61			
APPD					
APPD					PAGE 5.7

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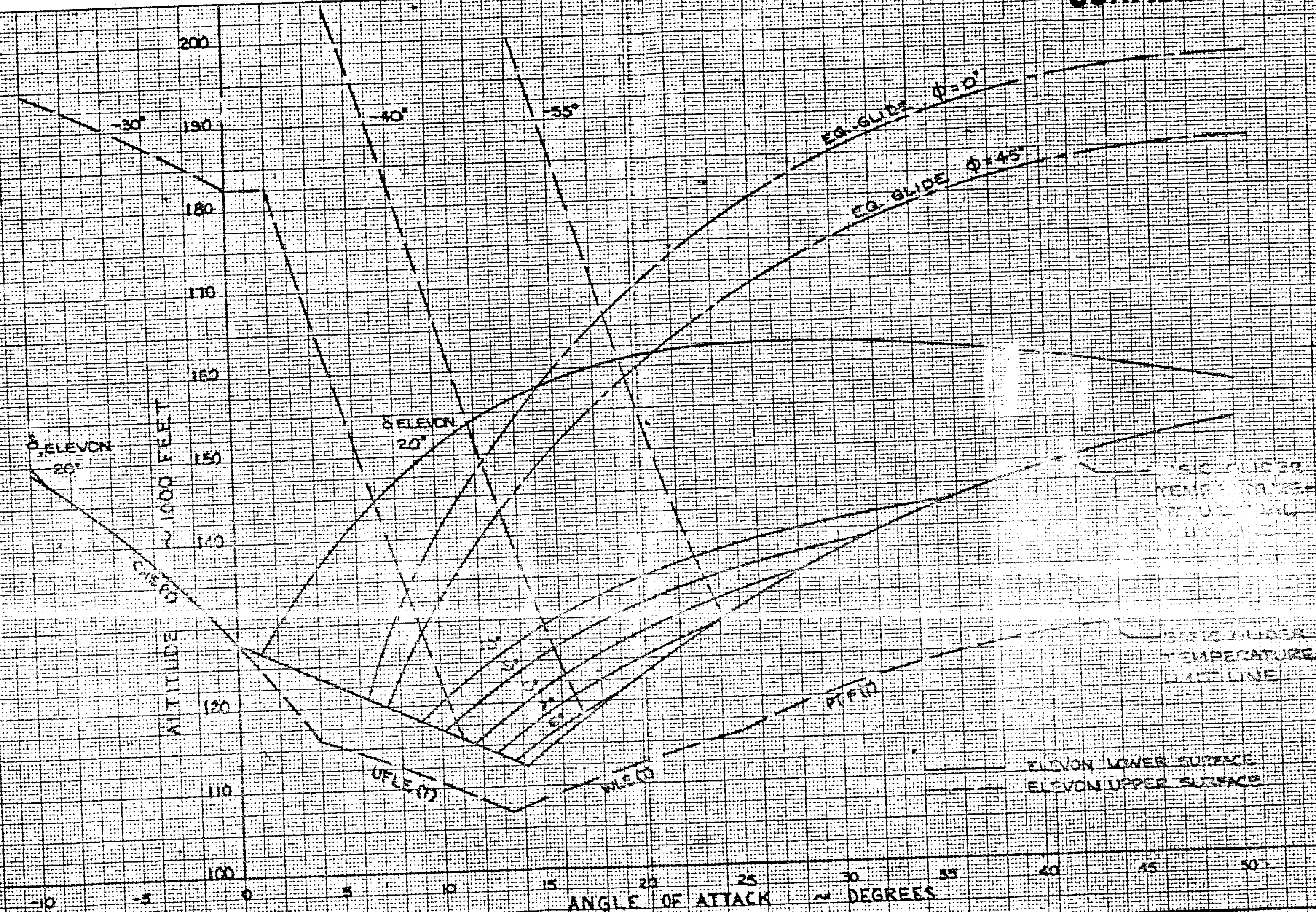

CALC	DWR	12-12-61	REVISED	DATE
CHECK	A.C.T.	12-12-61		
APPD				
APPD				

TEMPERATURE LIMIT ALTITUDES
ELEVONS , V = 10,000 FPS

PAGE 5.7

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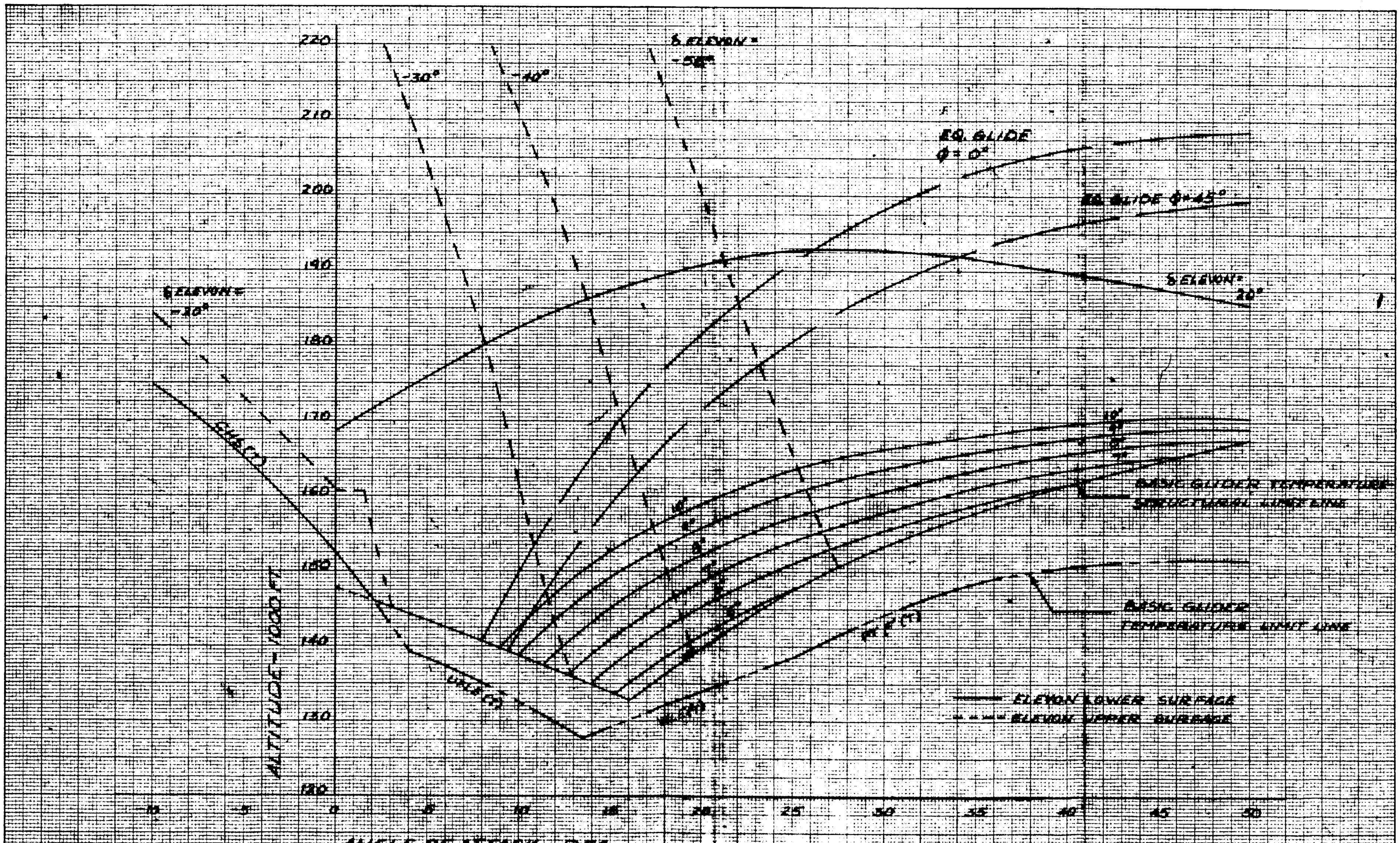
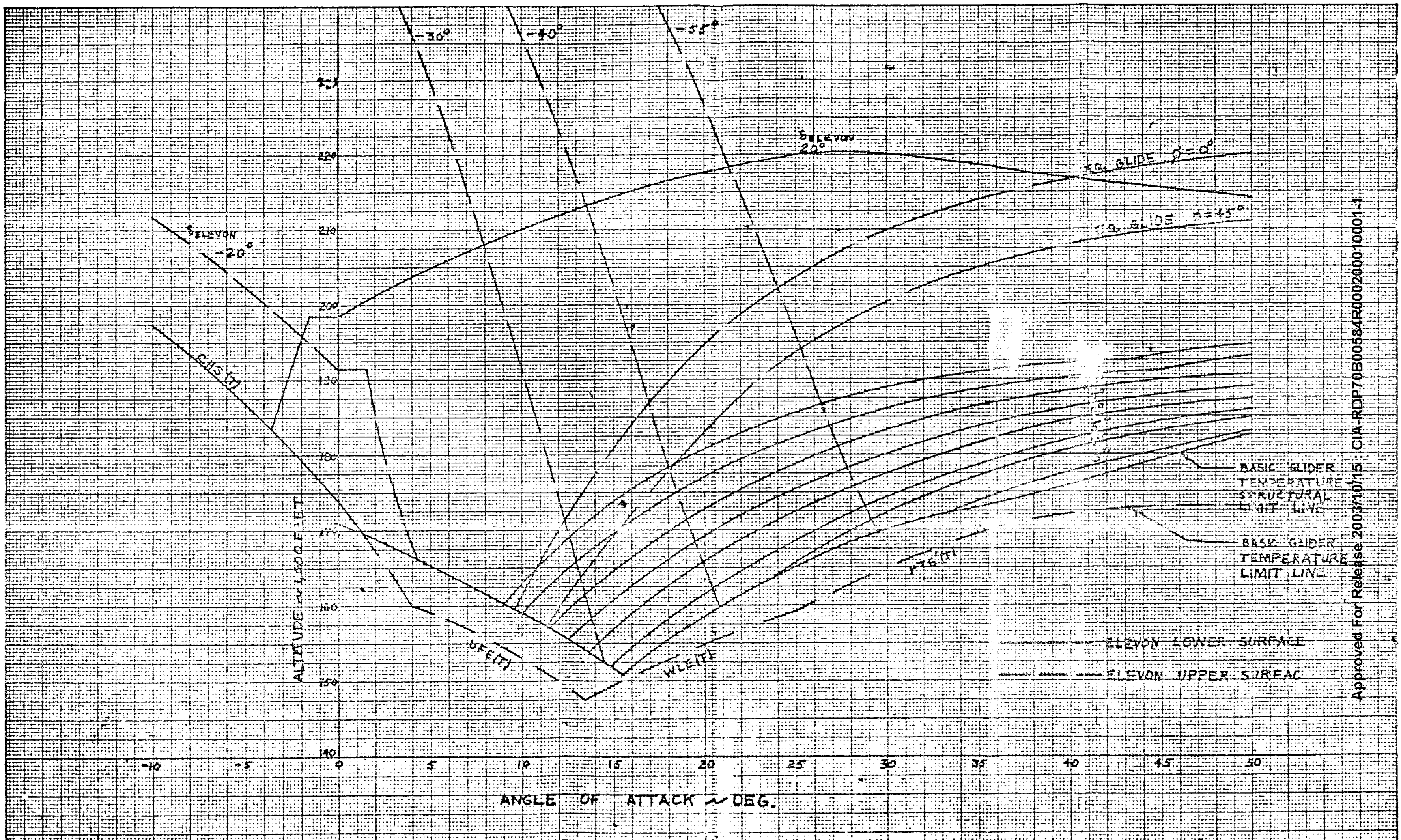
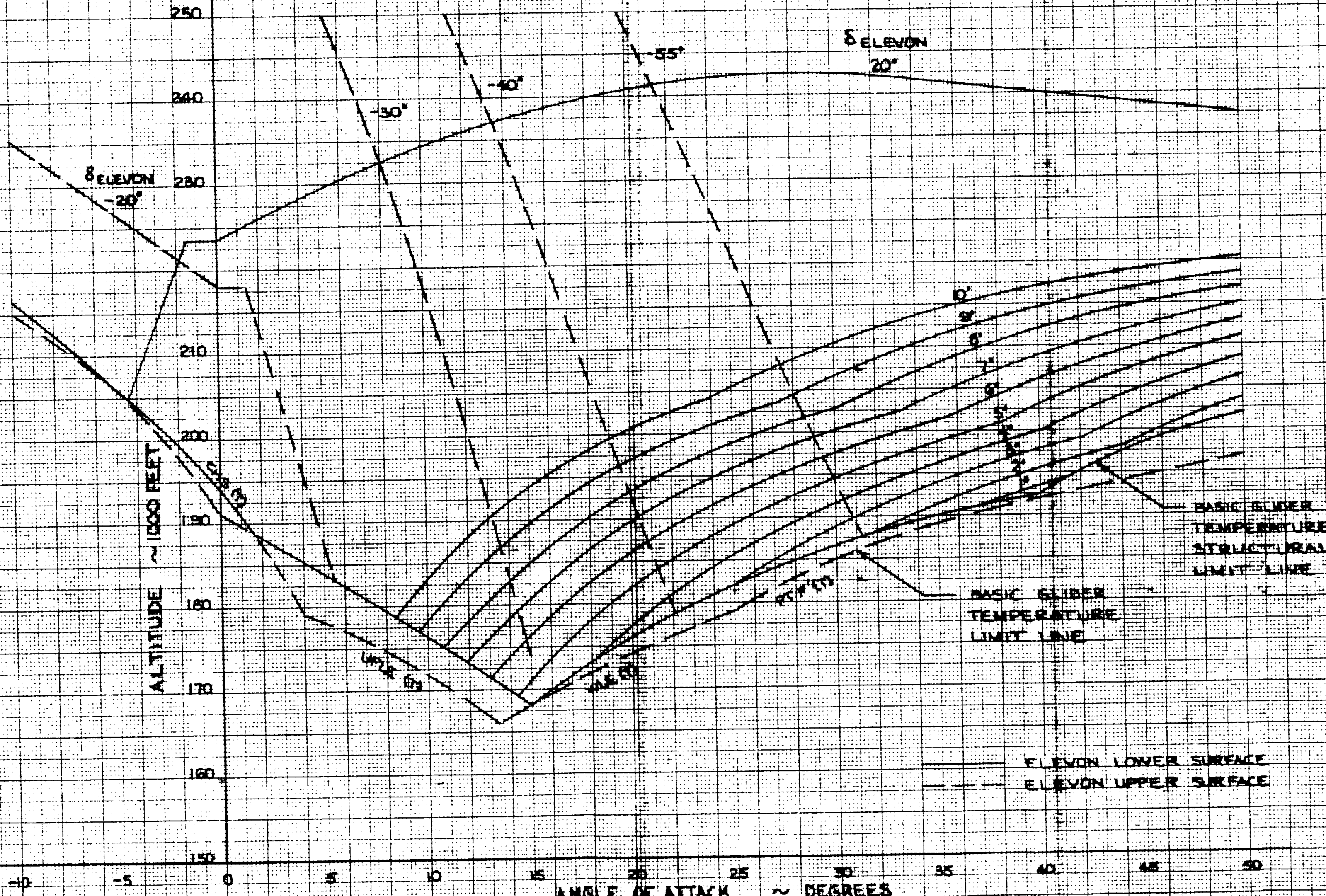


CALC	D.E. BRUMBY	12-11-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDE - ELEVONS V = 12,000 FPS	FIG. 56
CHECK	ACT			12-20-61		D2-80065
APPD						PAGE 59
APPD						



CALC	MR	12/3/60	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES	FIG. 5.11
CHECK	ACT				ELEVONS , V = 14,000FPS	D2 80045
APPD						PAGE 5.10
APPD						



CALC	[illegible]	12-6-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES	FIG. 5.8
CHECK	ACT	12-11-61		12-20-61	ELEVONS , V= 16,000 FPS	D2-80065
APPD						PAGE 5.11
APPD						

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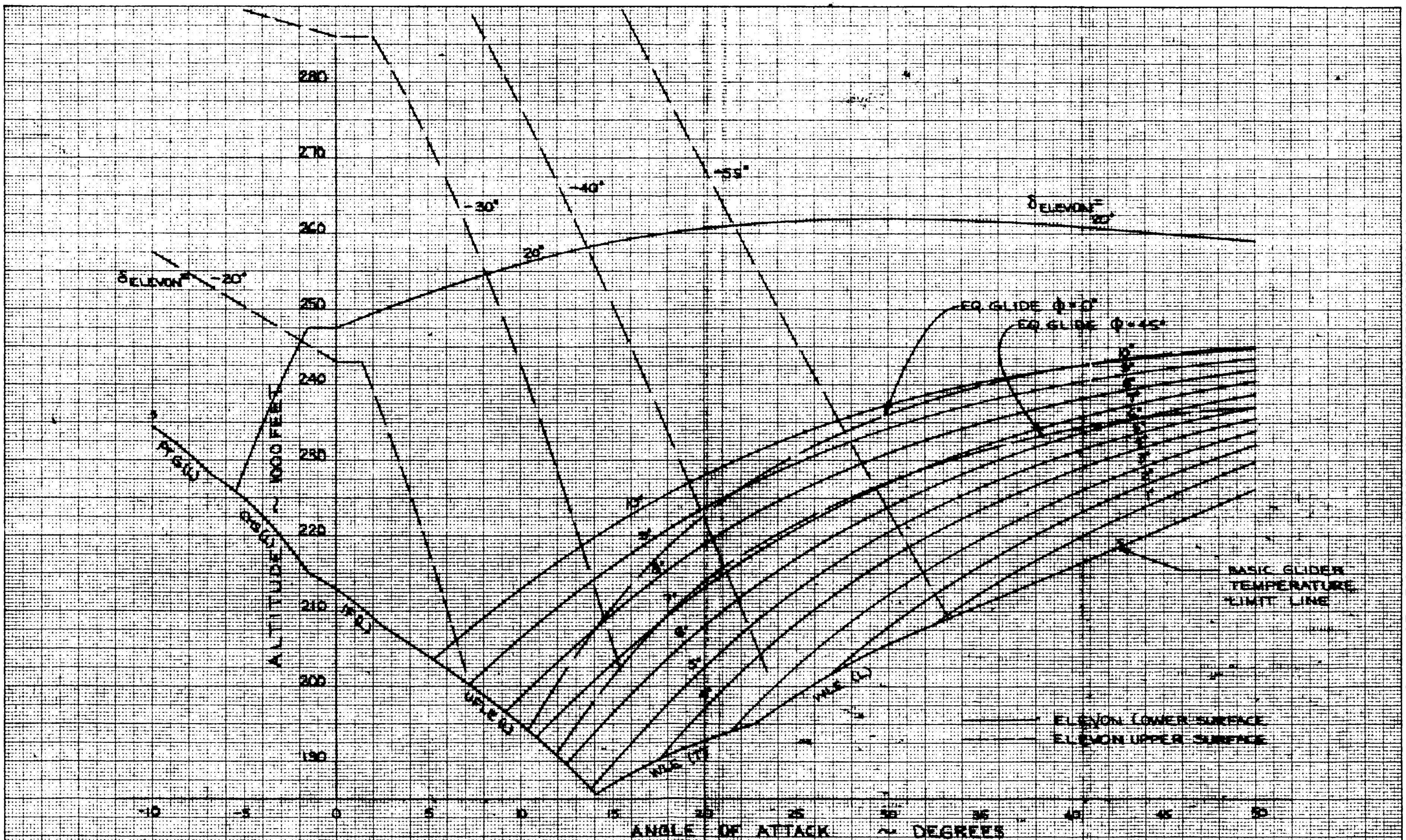
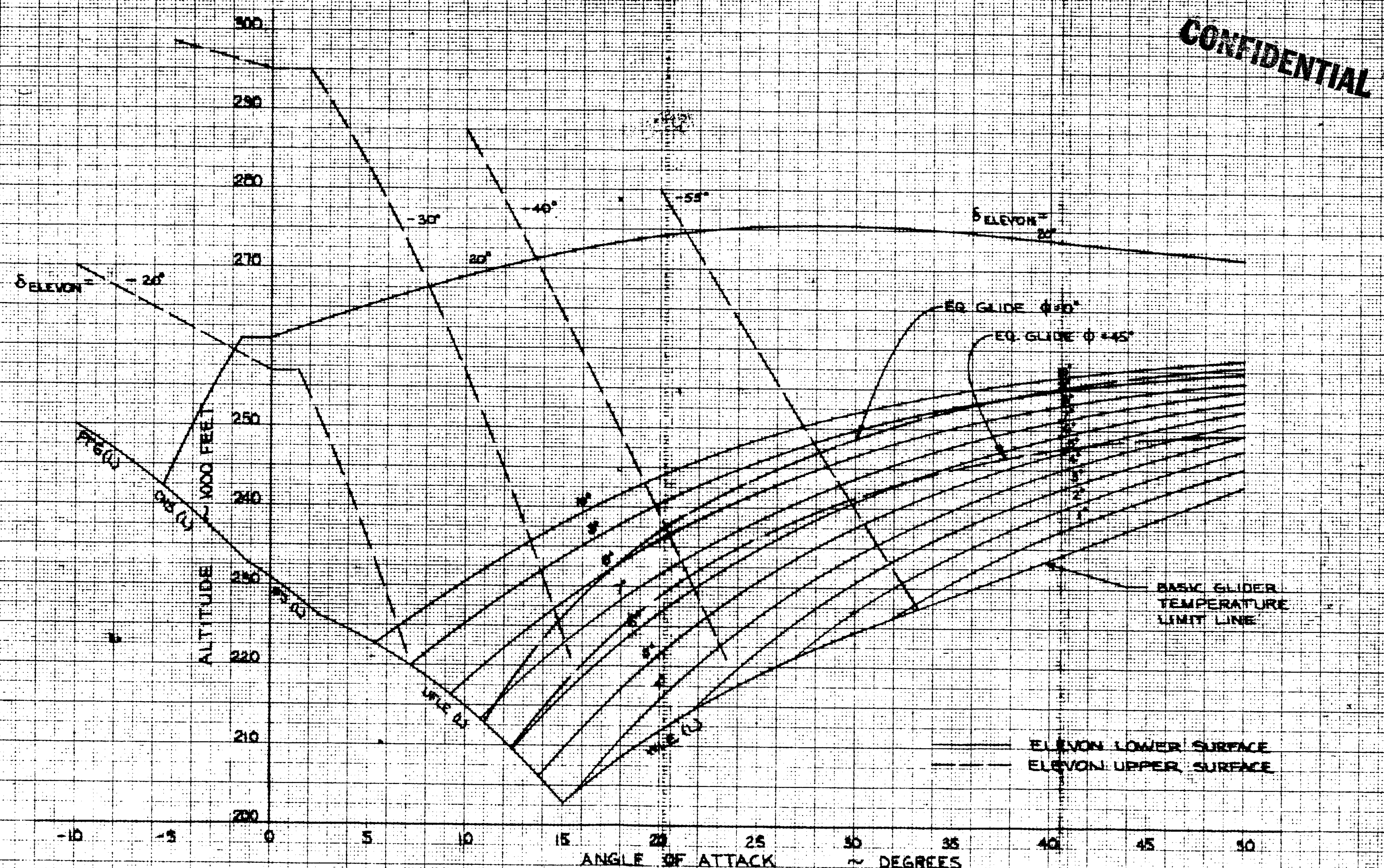


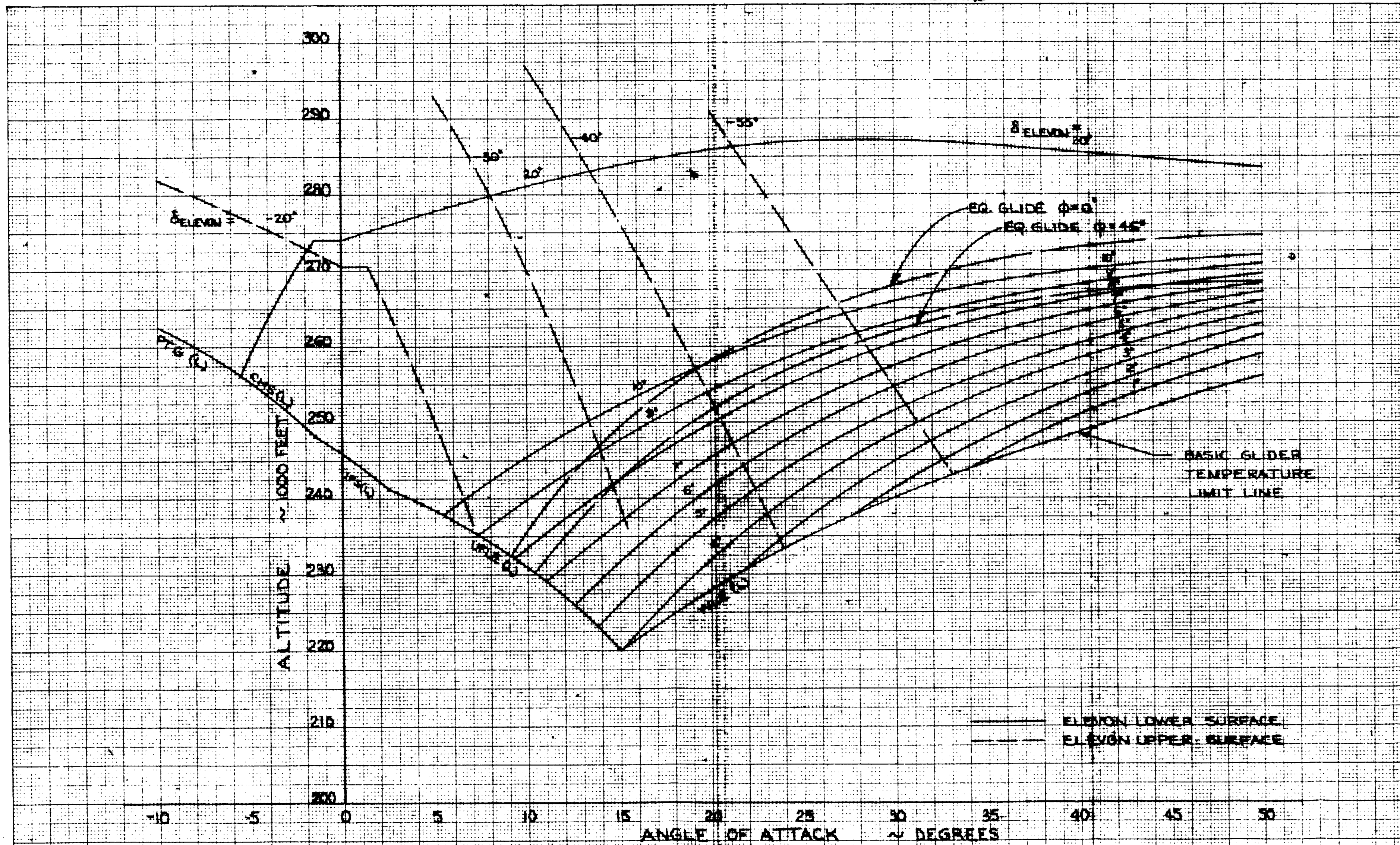
CALC		11-30-61	REVISED	DATE	TEMPERATURE UNIT ALTITUDES	FIG. 5.9
CHECK	AFT				ELEVONS, V = 18,100 FPS	D2-8005
APPD						PAGE 5.12
APPD						



CALC	BWR	11-29-61	REVISED	DATE
CHECK	ALT		BWR	12-6-61
APPD				12-20-61
APPD				

TEMPERATURE LIMIT ALTITUDES
ELEVONS , V = 20,700 FPS

FIG 5.10
D2-80065
PAGE 5.13



CALC	BWR	11-29-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES	FIG. 5-11
CHECK	ACT	12-11-61	BWR	12-6-1	ELEVONS , V= 23,000 FPS	D2-80065
APPD				12-21-1		PAGE 5.14
APPD						

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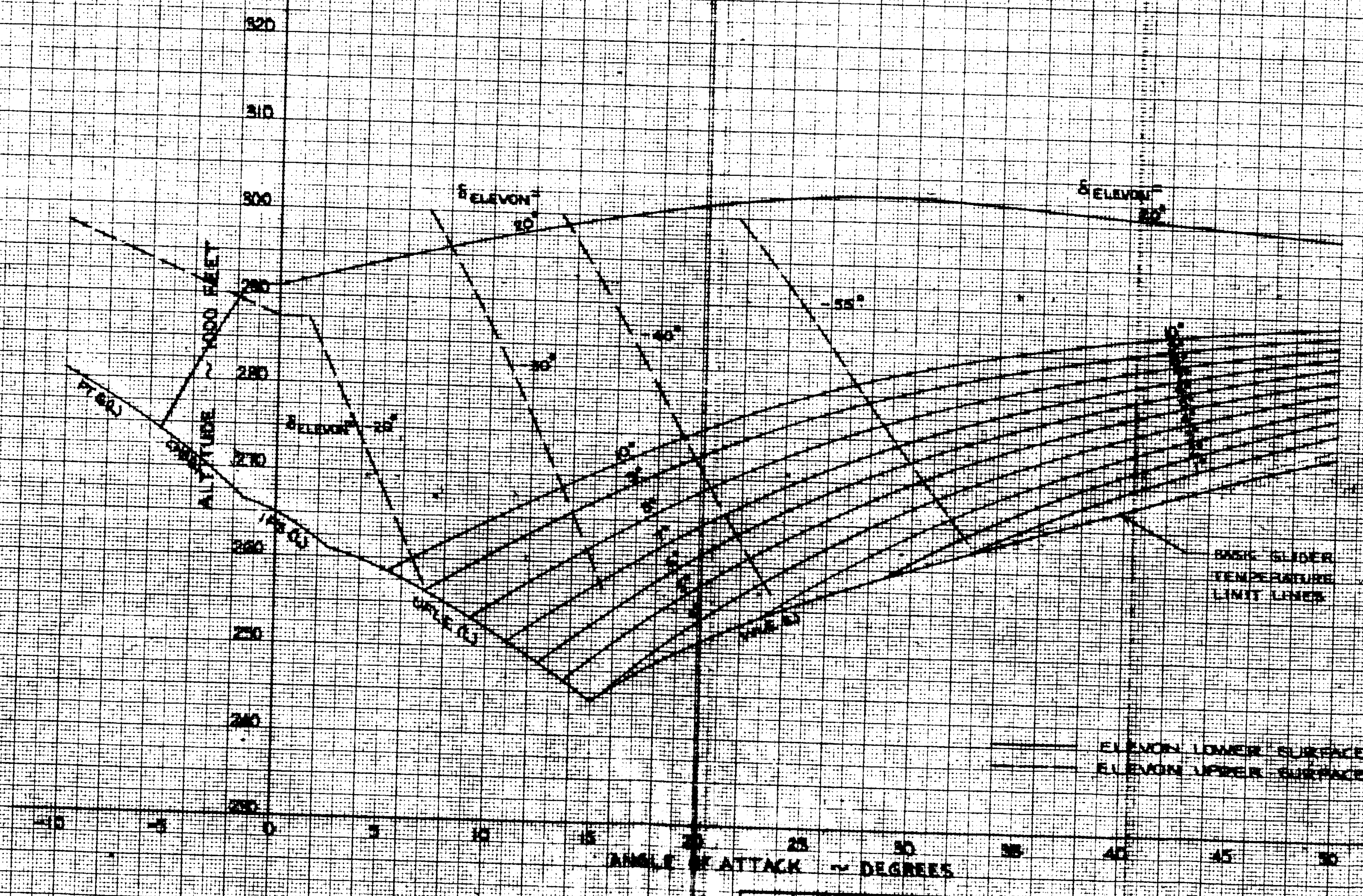


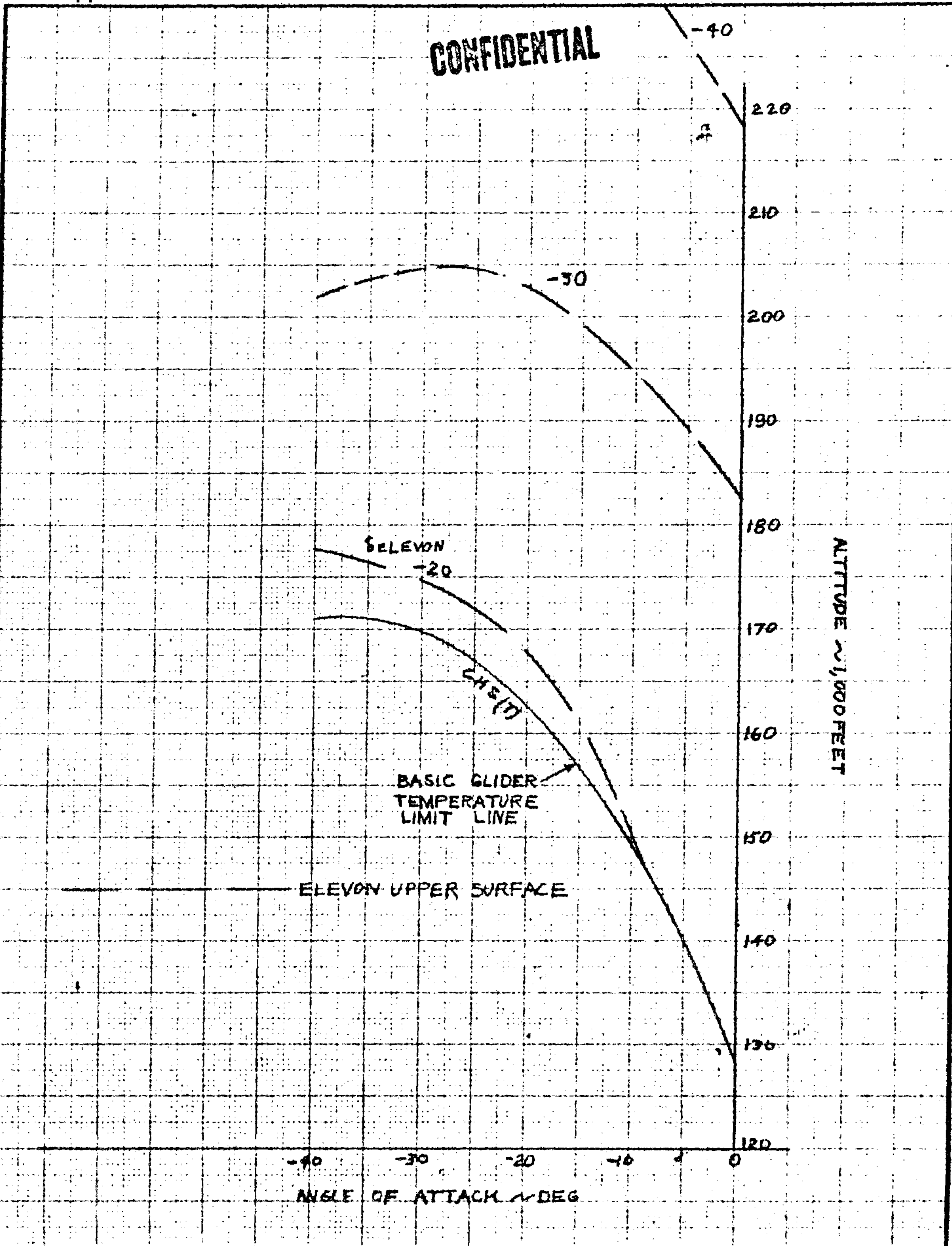
CALC		CHECK	A.C.T.	REVISED	DATE
APPD			12-20-61		

TEMPERATURE LIMIT ALTITUDES ELEVONS V = 27000 FPS

FIG. 5.12

D2-80065

PAGE 5.16



CALC	MQ	12/1/61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES ELEVONS , V = 10,000 FPS	FIG 5.13
CHECK	DSP	12-3-61	12-?-1			D2-80065
APR					THE BOEING COMPANY	PAGE 5.16
APR						

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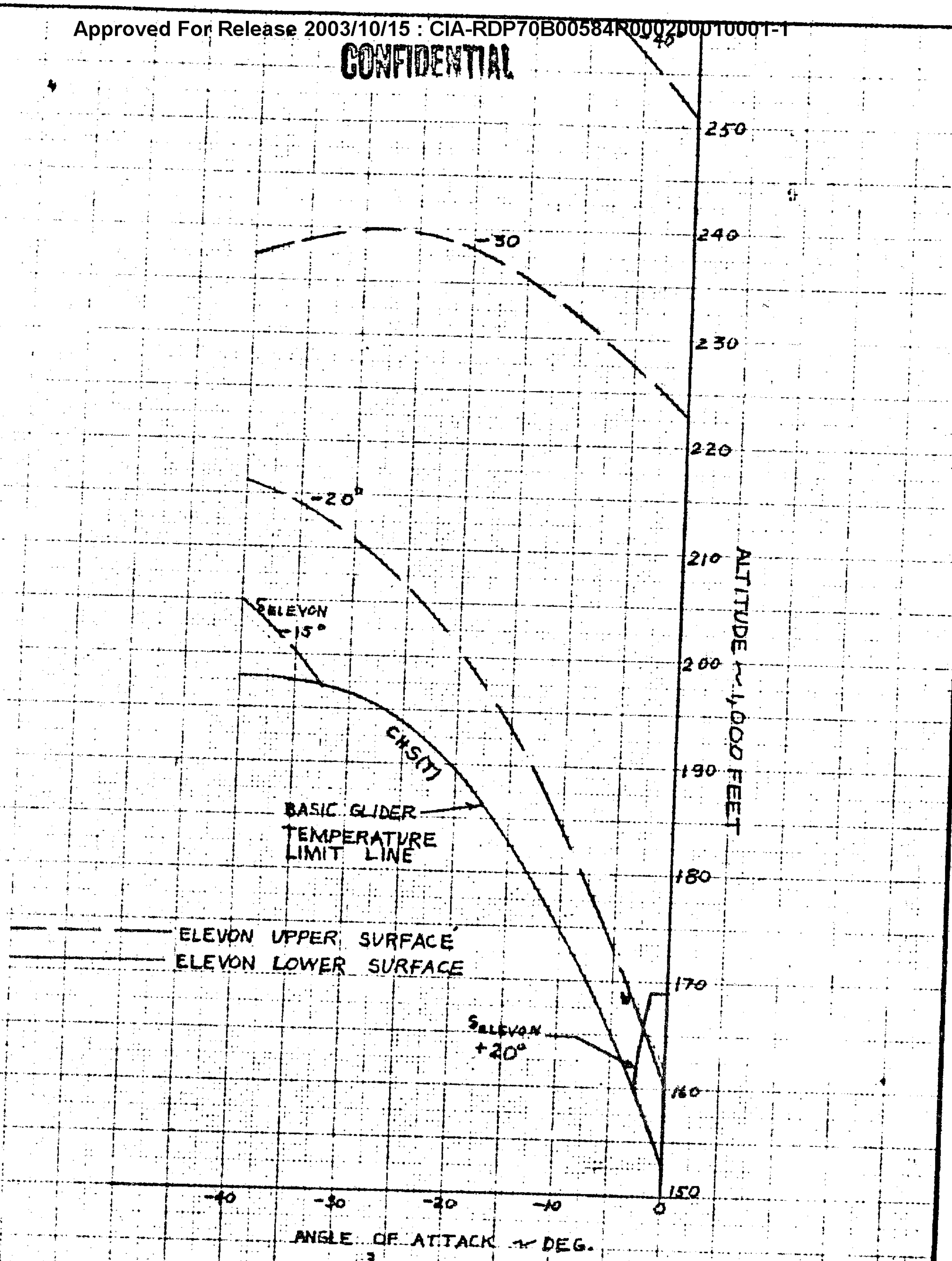

CALC			REVISED	DATE	TEMPERATURE LIMIT ALTITUDE ELEVONS , V=12,000FPS	FIG 5.14
CHECK		2-13	12-?-1			D2-80065
APR					THE BOEING COMPANY	PAGE 5.17
APR						

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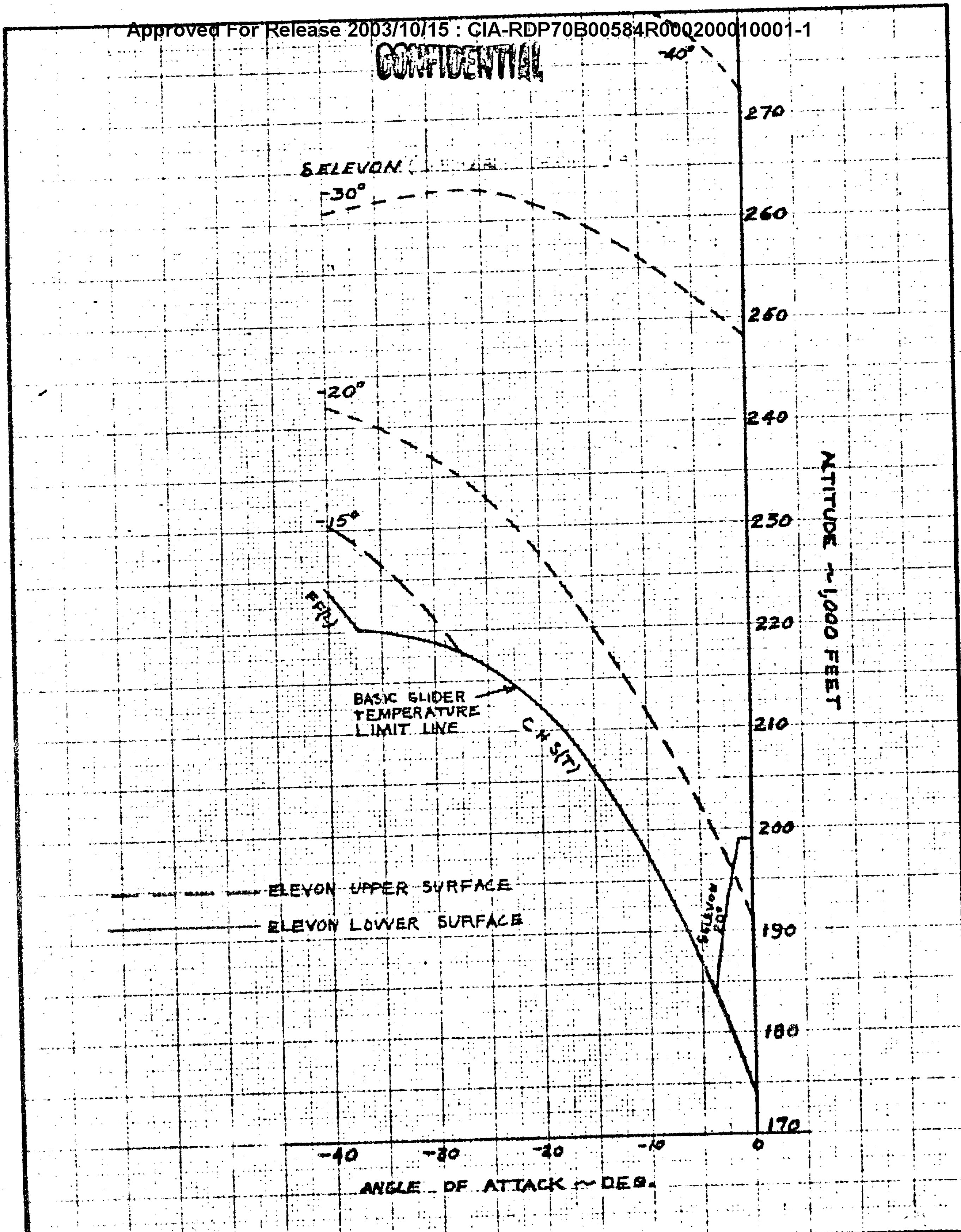

			REVISED	DATE		
CALC	M.F.	12-1-61			TEMPERATURE LIMIT ALTITUDE ELEVONS V = 14,000 FPS	FIG 5.15
CHECK	D.E.B.	12-13-61	12-20-61			D2-80065
APR					THE BOEING COMPANY	PAGE 5.18
APR						

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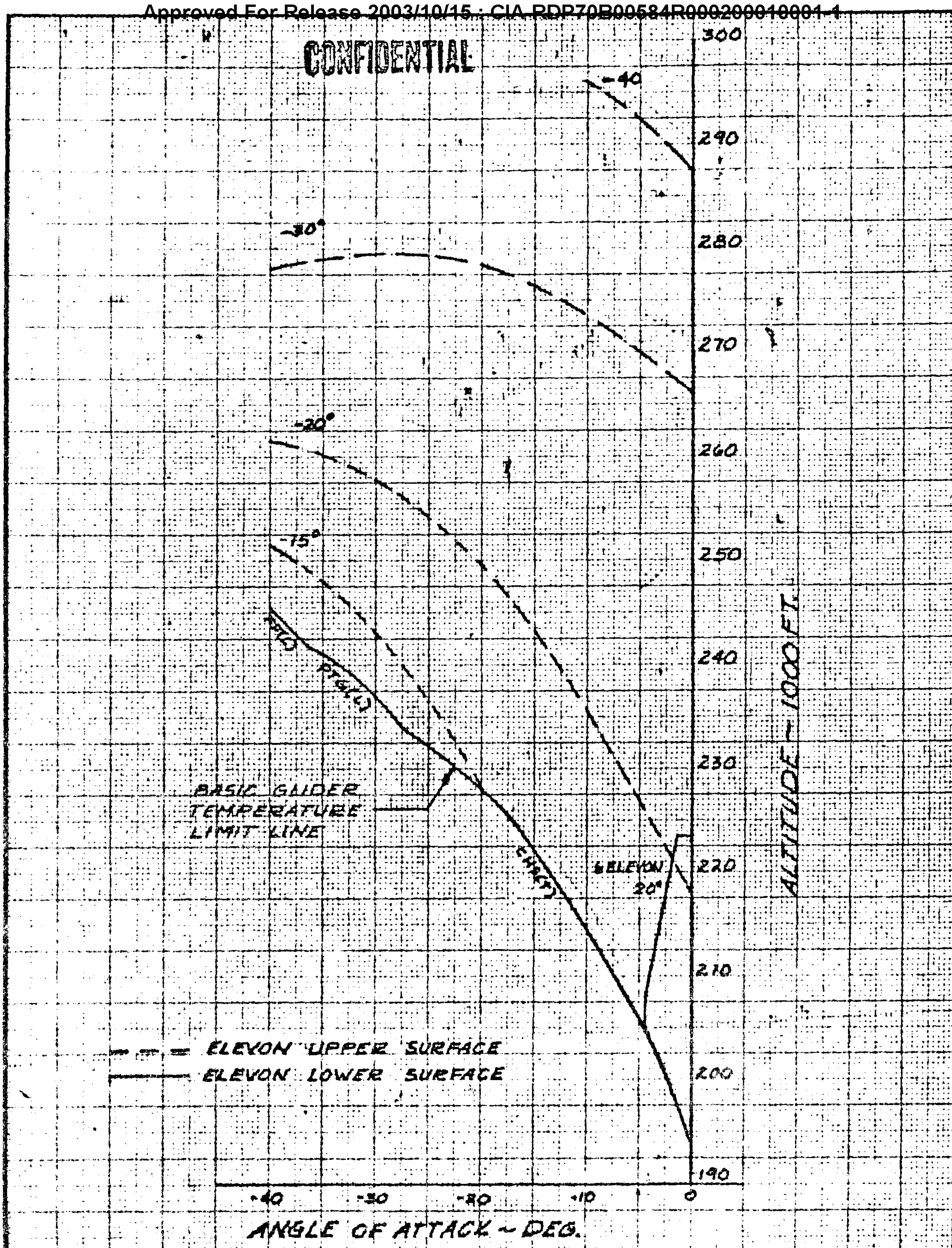

CALC	D.E. BENNETT	12-12-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDE ELEVONS - V=16,000 FPS	FIG 5.16
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 5.19
APR						

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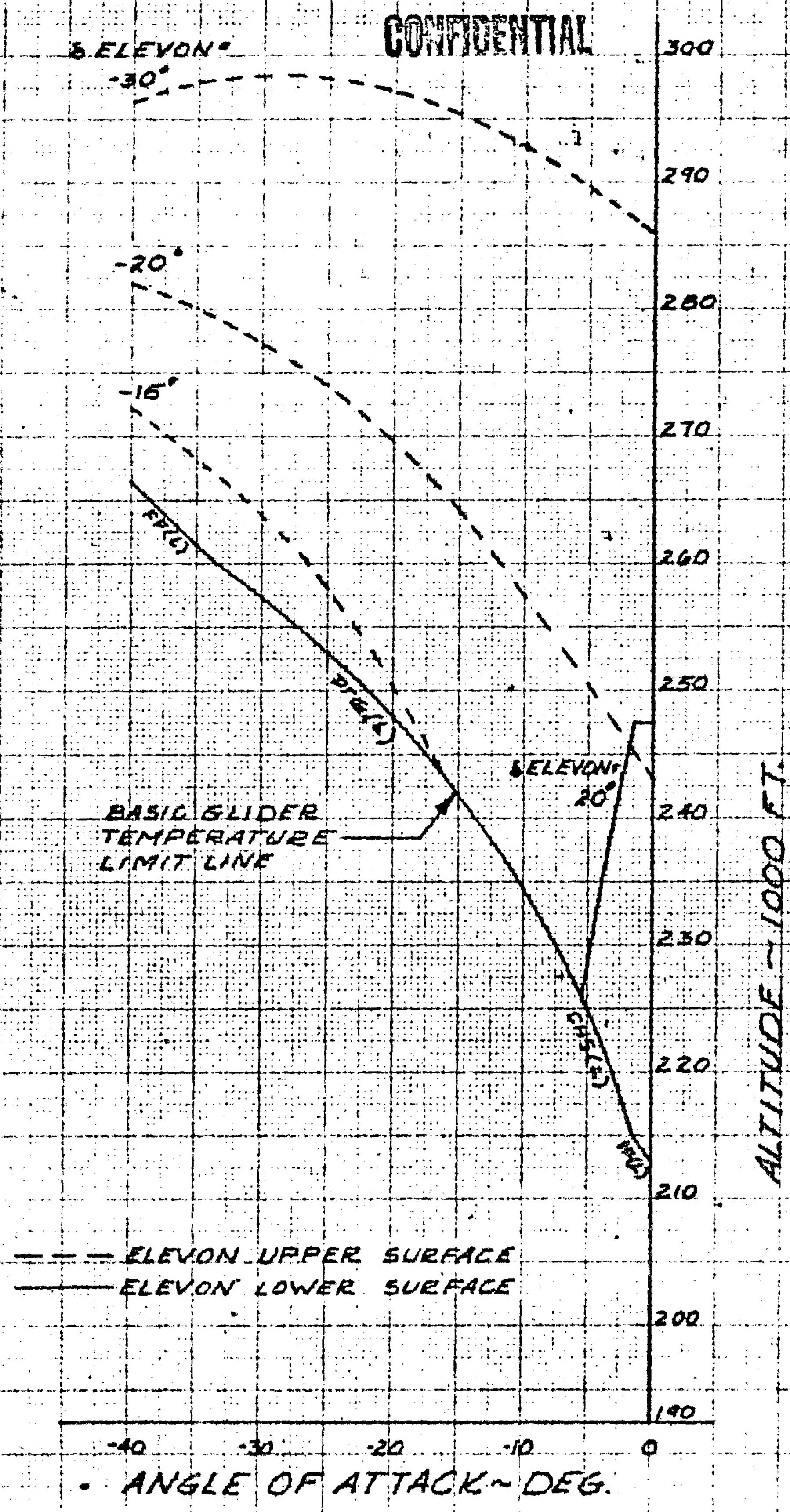

CALC	D.E. BENNETT	12-13-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDE ELEVONS – V=18,700 FPS	FIG 5.17
CHECK	ACT	12-3-61				D2-80065
APR					THE BOEING COMPANY	PAGE 5.20
APR						

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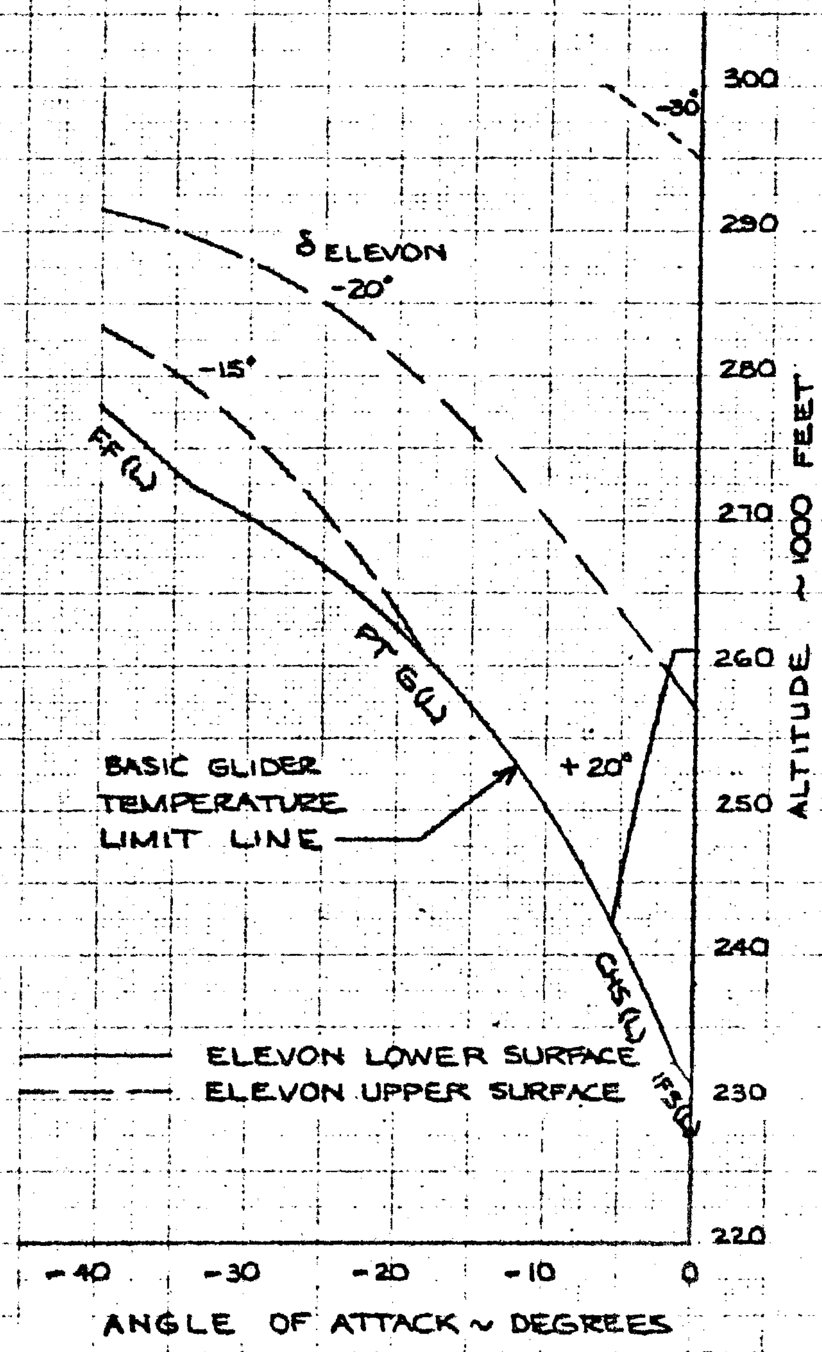
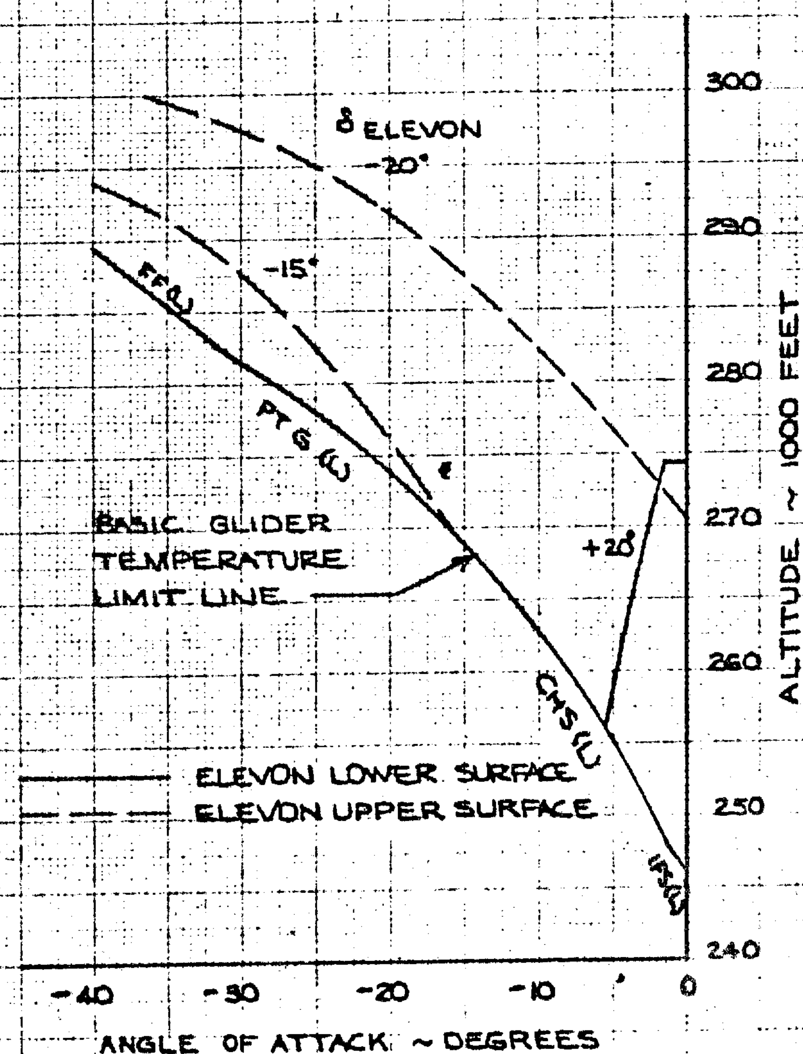


CALC	BWR	12-13-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDE ELEVONS , V = 20,700
CHECK	A.T	12-13-61			
APR					THE BOEING COMPANY
APR					

FIG 5.18

D2-80065

PAGE 5.21



CALC	BWR	12-12-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDE ELEVONS , V = 23000 FPS
CHECK	ACT	12-13-61			
APR					
APR					THE BOEING COMPANY

FIG 5.19

D2-80065

PAGE 5.22

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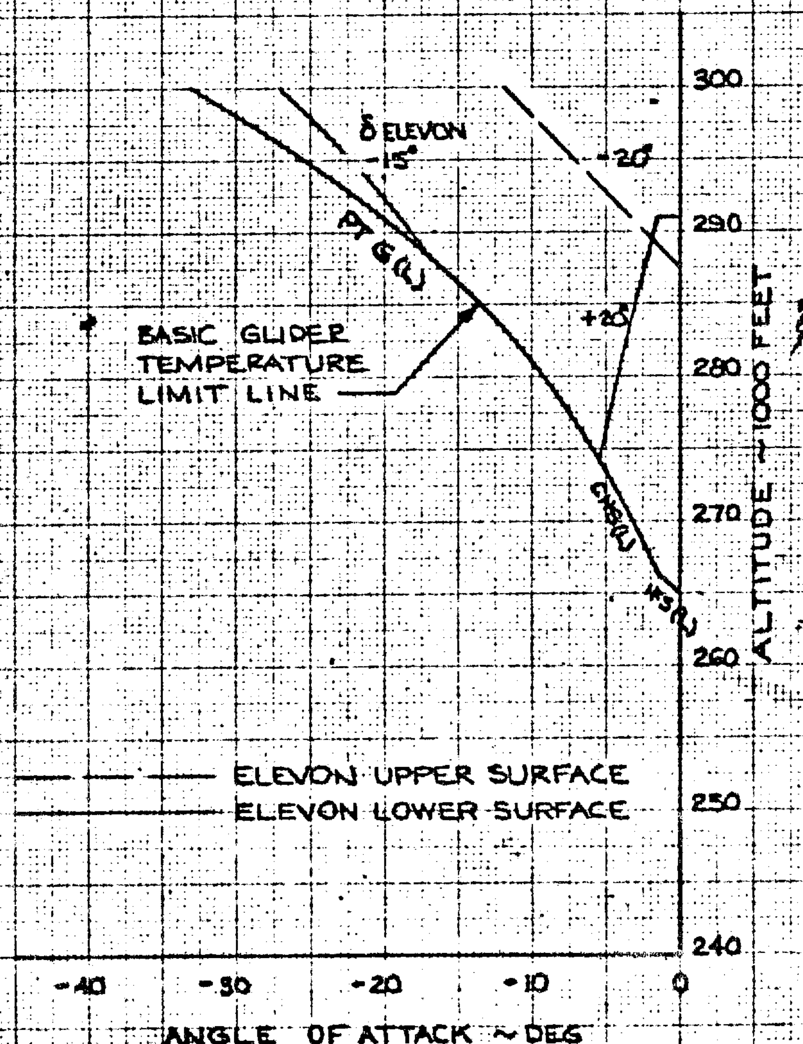

CALC	BWR	12-8-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES ELEVONS , V = 27000 FPS	FIG 5.20
CHECK	ACT	12-12-61				D2-80065
APR					THE BOEING COMPANY	PAGE 5.23
APR						

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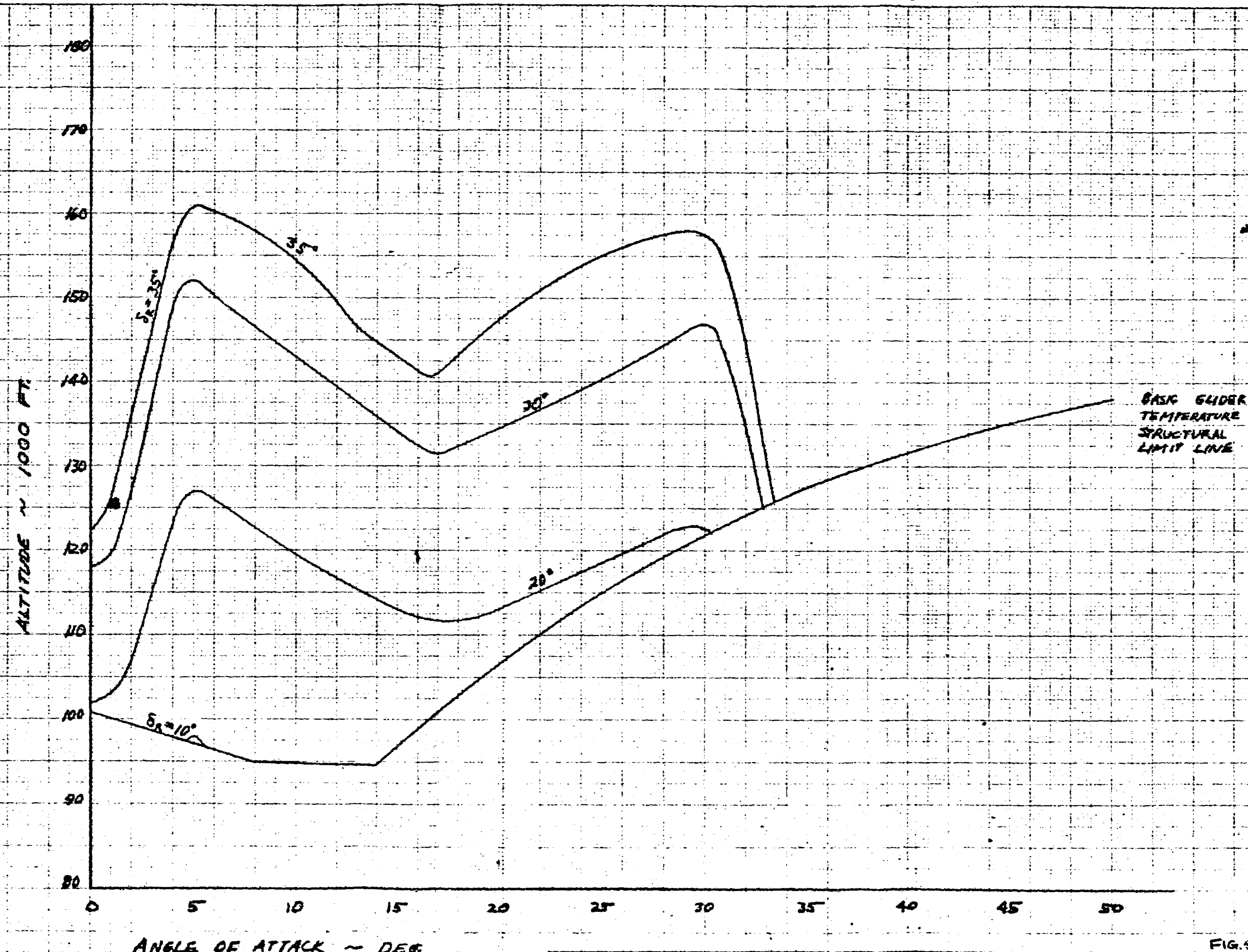
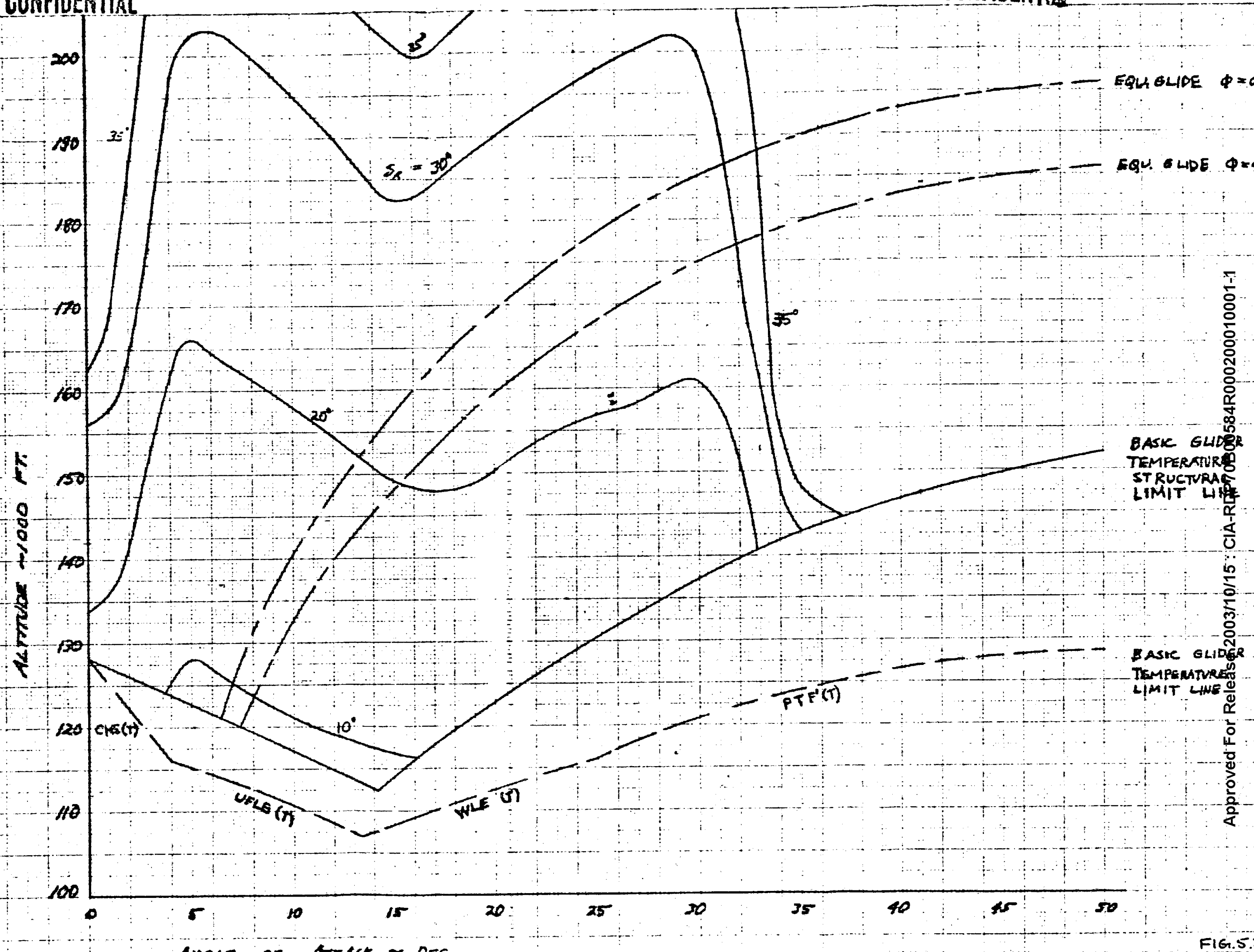


FIG. 5.21

CALC	F. E. Kaiser		REVISED	DATE	TEMP. LIMIT ALTITUDE RUDDER V = 8000 FPS	844-2050 D
CHECK	DE 23	12-19-61				D2-80065
APPD						PAGE 5.24
APPD						

Approved For Release 2003/10/15 : CIA-RDP70B00584R000200010001-1



CALC	C.R. Russell	12-18-61	REVISED	DATE
CHECK	DEB	12-19-61		
APPD				
APPD				

TEMPERATURE LIMIT ALTITUDES
RUDDER
V=10,000 FPS

FIG. 5.22
844-2050D
D2-80065
PAGE 5.25

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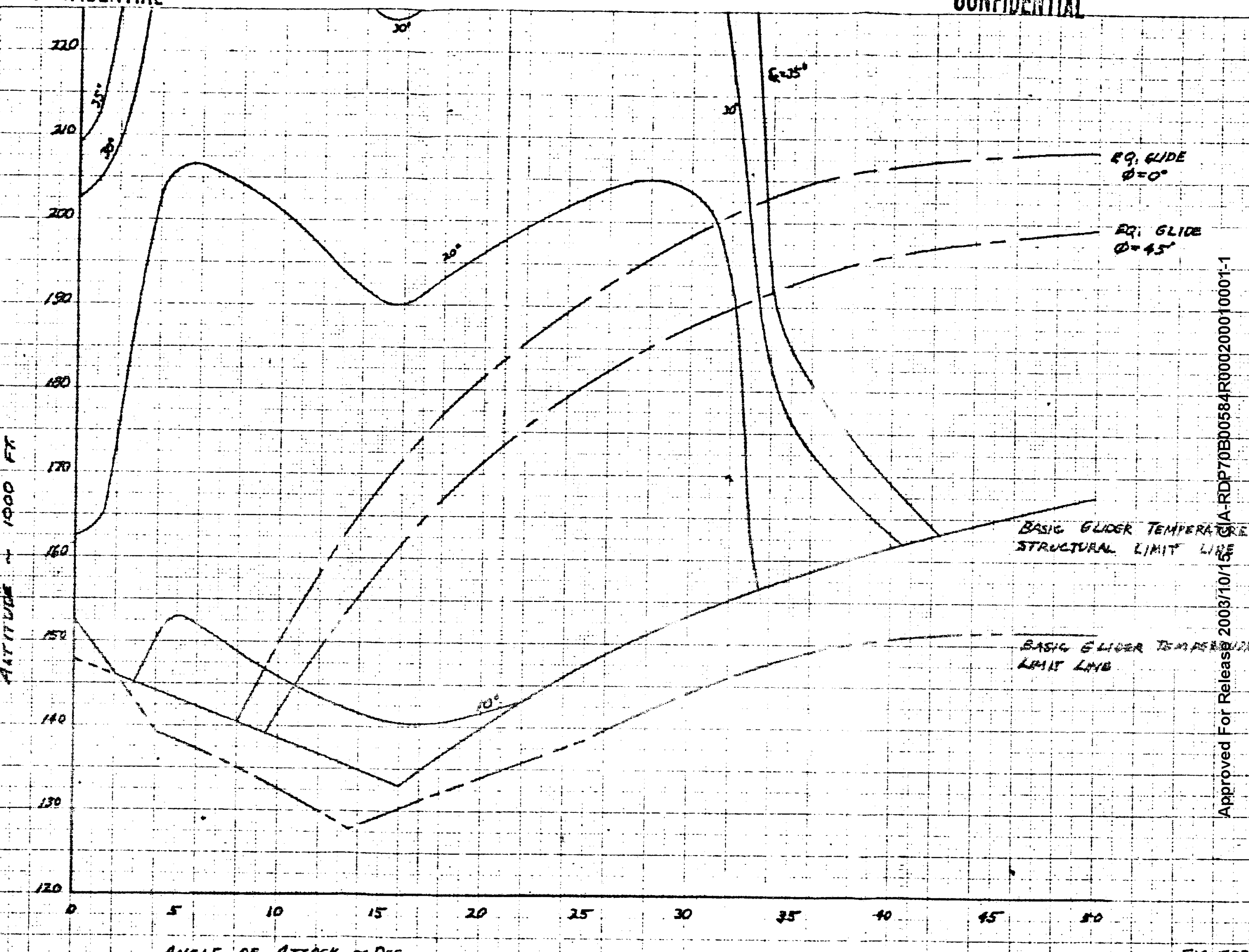

CALC	CRR		REVISED	DATE
CHECK	AcT			
APPD				
APPD				

TEMPERATURE LIMIT ALTITUDES
RUDDER
V = 12,000 FPS

FIG. 5.23
844-2050D
D2-80065
PAGE 5.26

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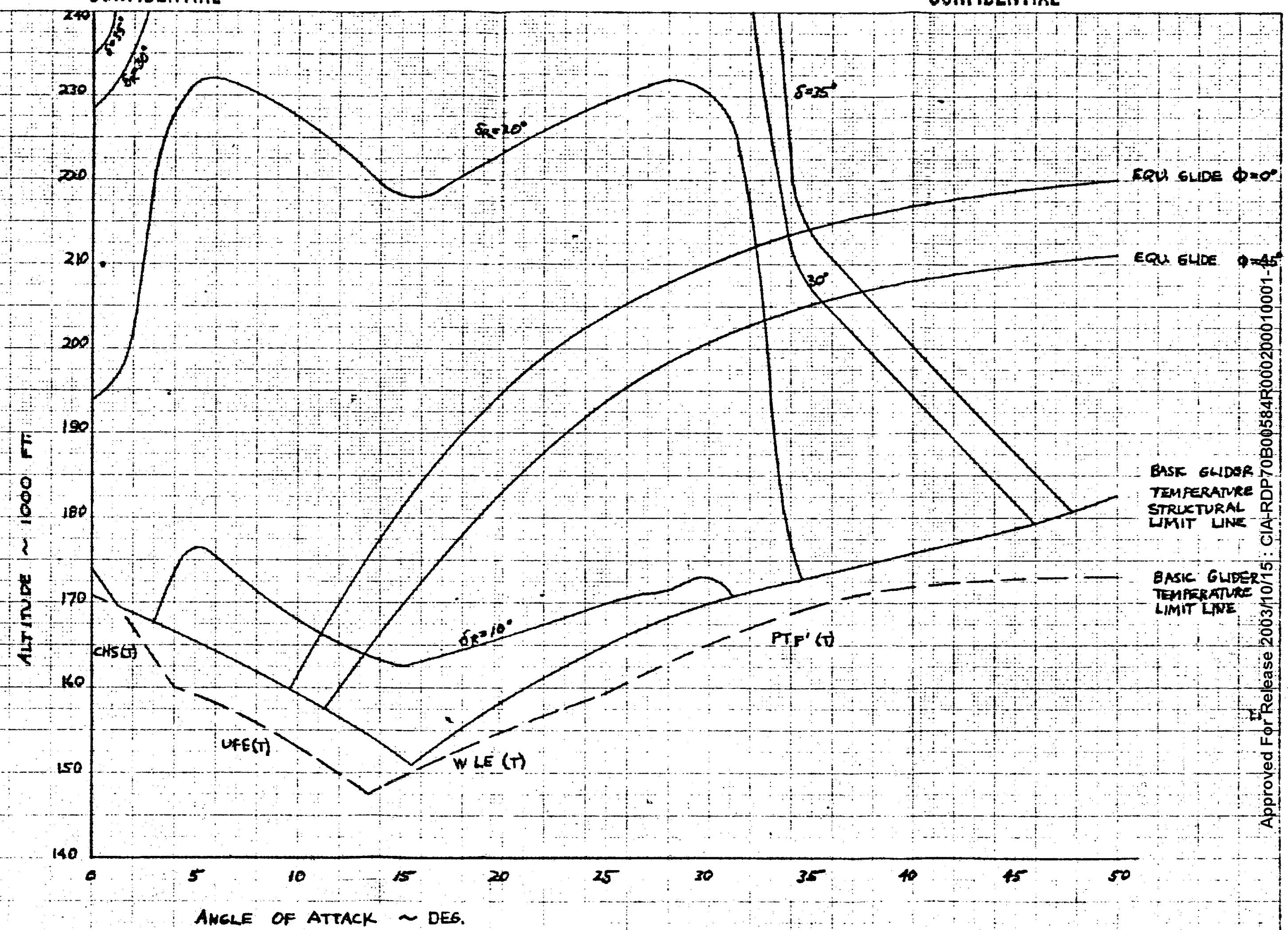
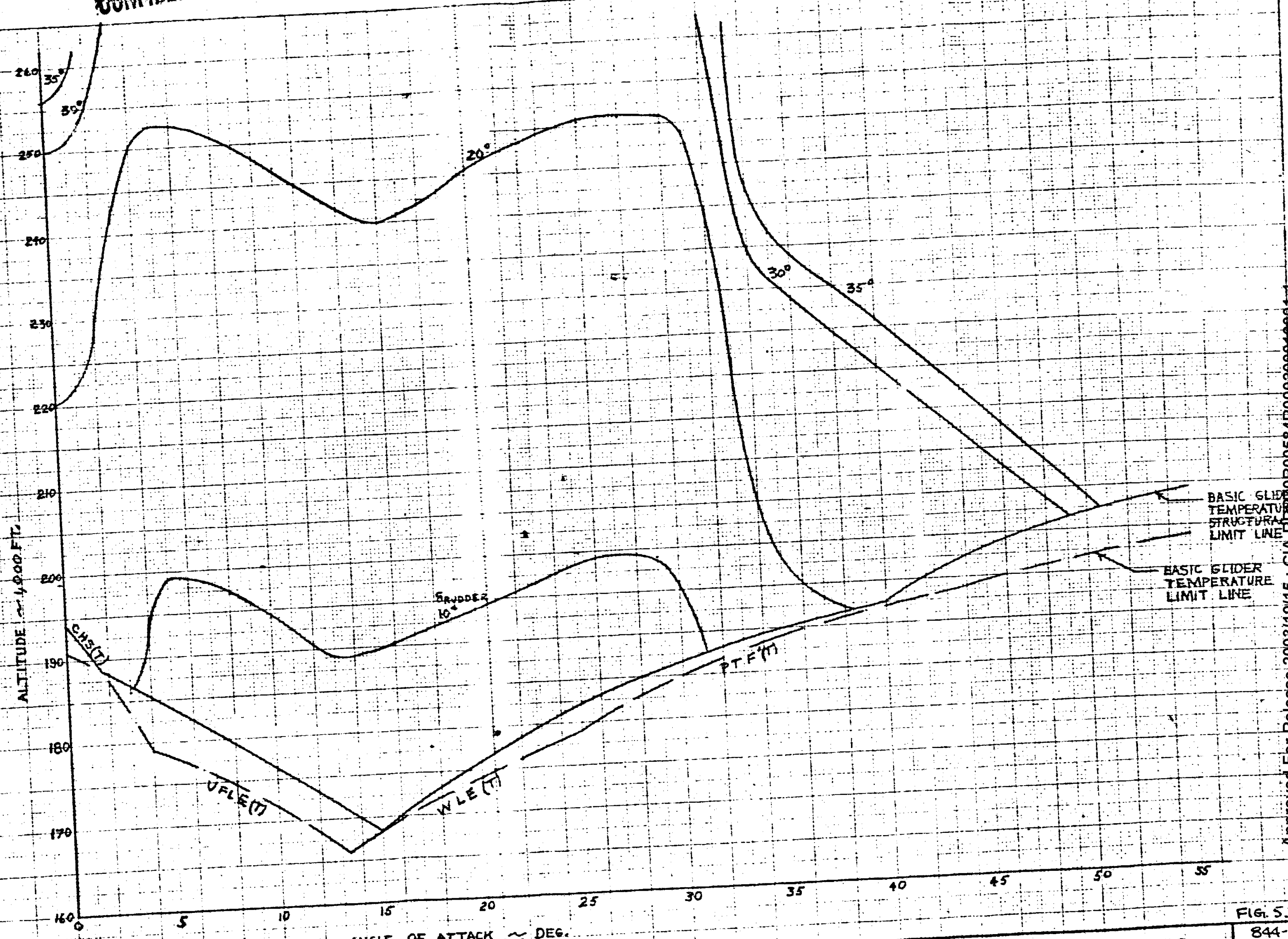


CALC	C.R. Russell		REVISED	DATE	TEMPERATURE LIMIT ALTITUDES RUDDER V= 14,000 FPS	FIG. 5.24 844-2050D
CHECK	DEB	12-19-6[illegible]	[illegible]			D2-80065
APPD						PAGE 5.27
APPD						



CALC	M. R.	12/13/61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES	FIG. 5.25
CHECK	TDES	12-13-61	12-20-61		RUDDER	844-2050 D
APPD					V = 16,000 FPS	D2-80065
APPD						PAGE 5.28

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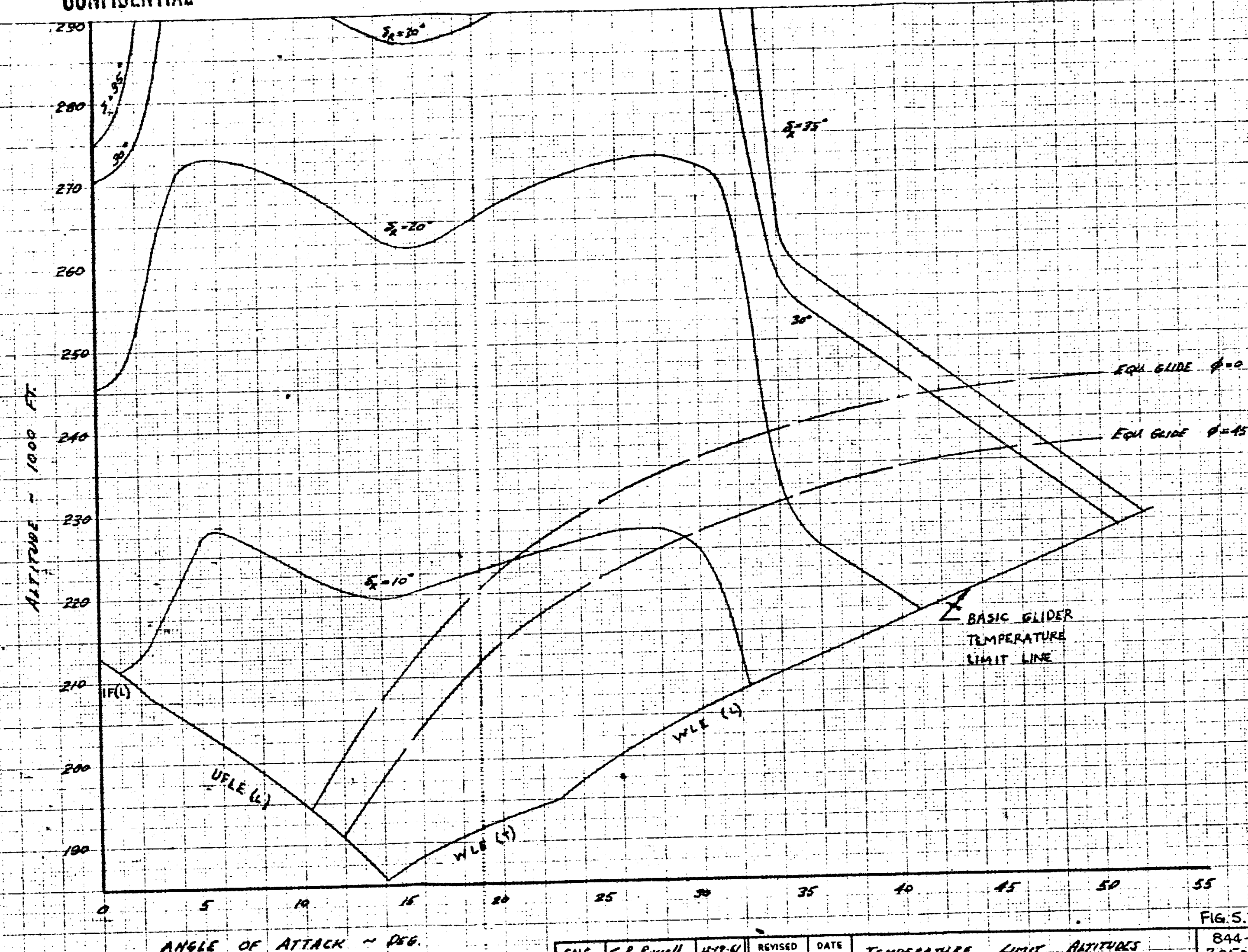

CALC	C.R. Russell	12-19-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES RUDDERS V=18 700 FPS	FIG. 5.26 844-2050D
CHECK	T.D.B.	12-19-61				D2-80065
APPD						PAGE 5.29
APPD						

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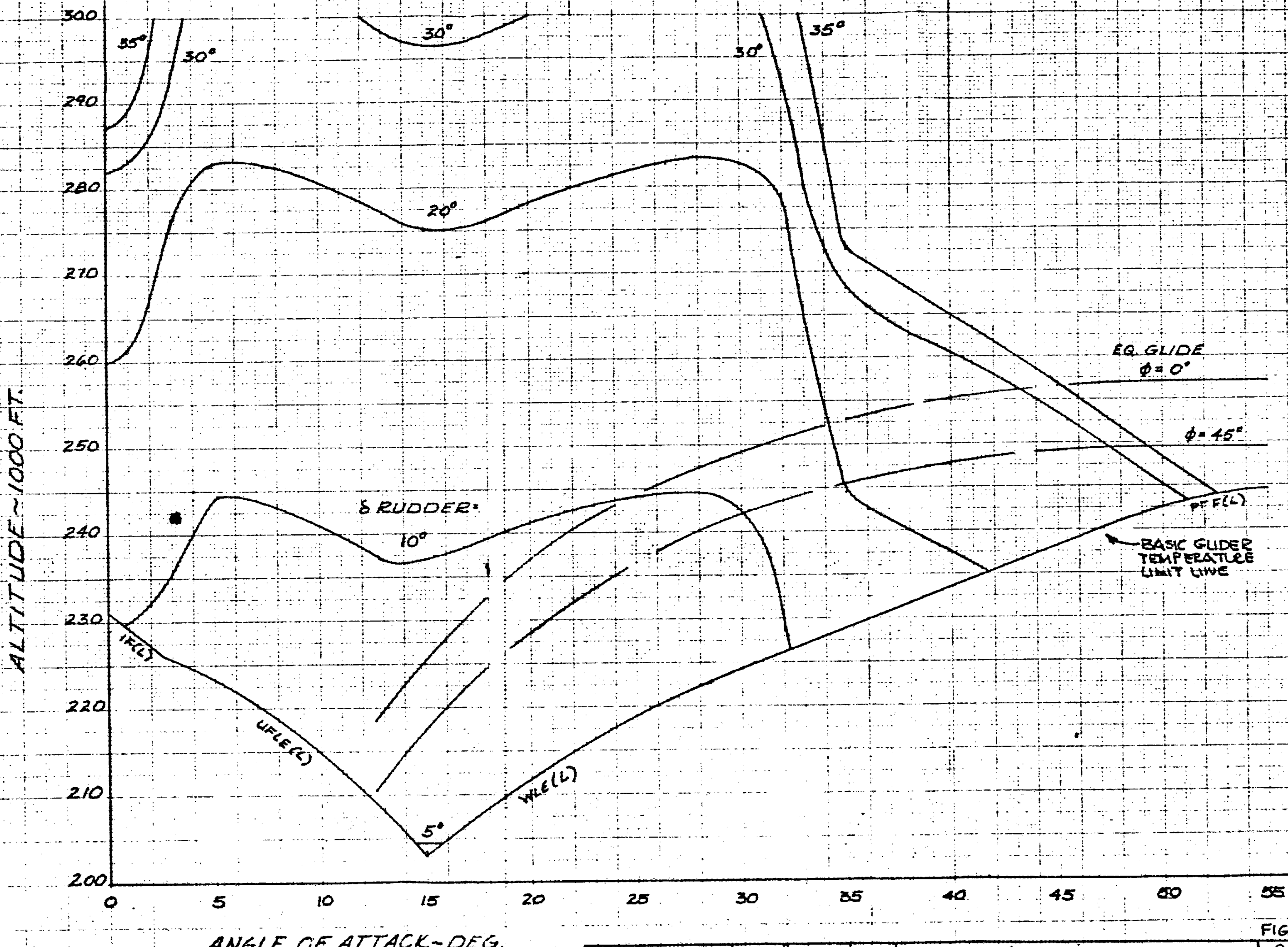

FIG. 5.27

CALC	D.E. BENNETT	12-19-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDE RUDDERS V = 20,700 FPS	844-2050D
CHECK	T.D.B.					D2-80065
APPD						PAGE 5.30
APPD						

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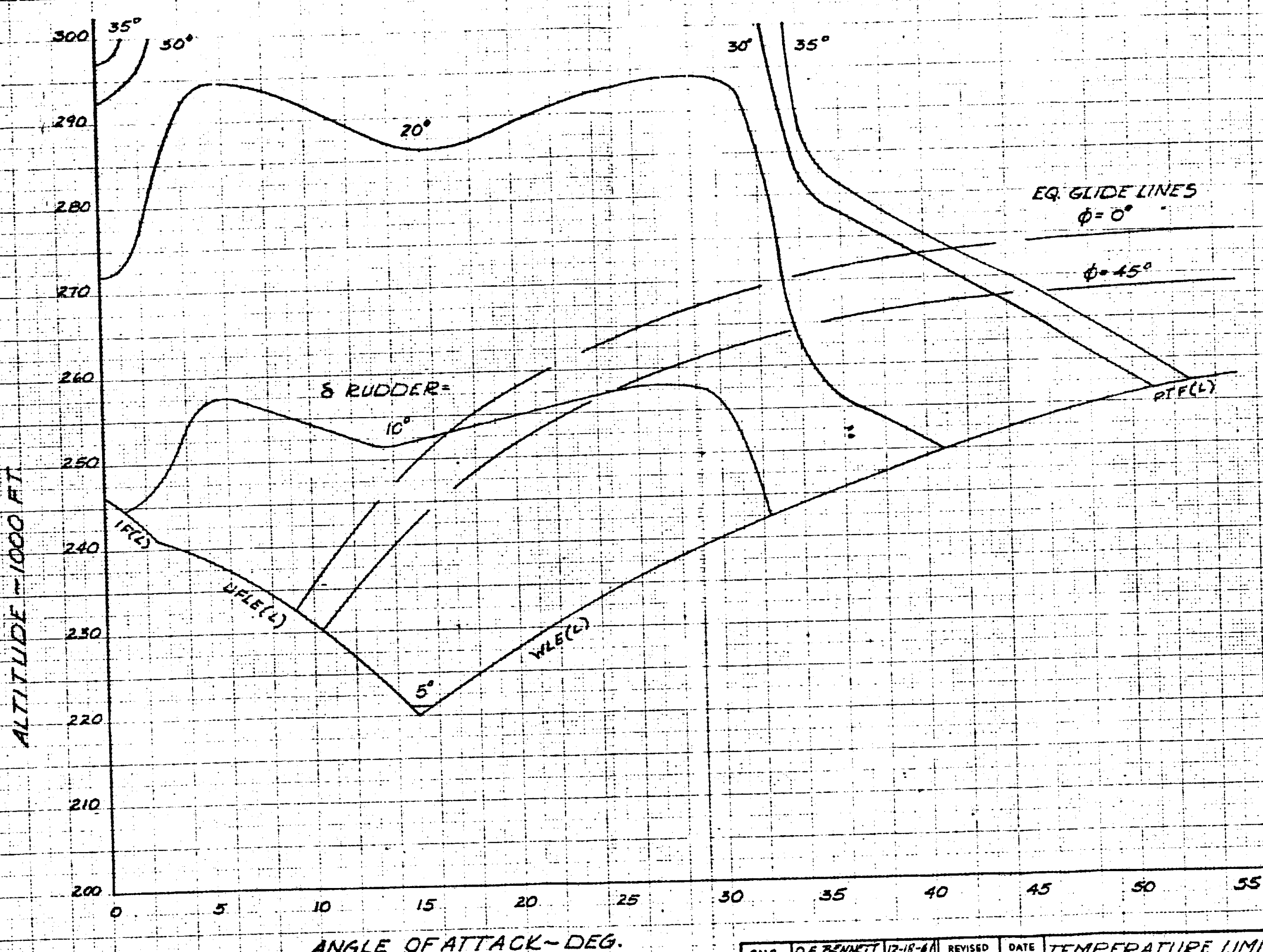

CALC	D.E. BENNETT	12-18-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES RUDDERS V=23,000 FPS
CHECK	ACT	12/?/61			
APPD					
APPD					

FIG. 5.28

844-2050D

D2-80065

PAGE 5.31

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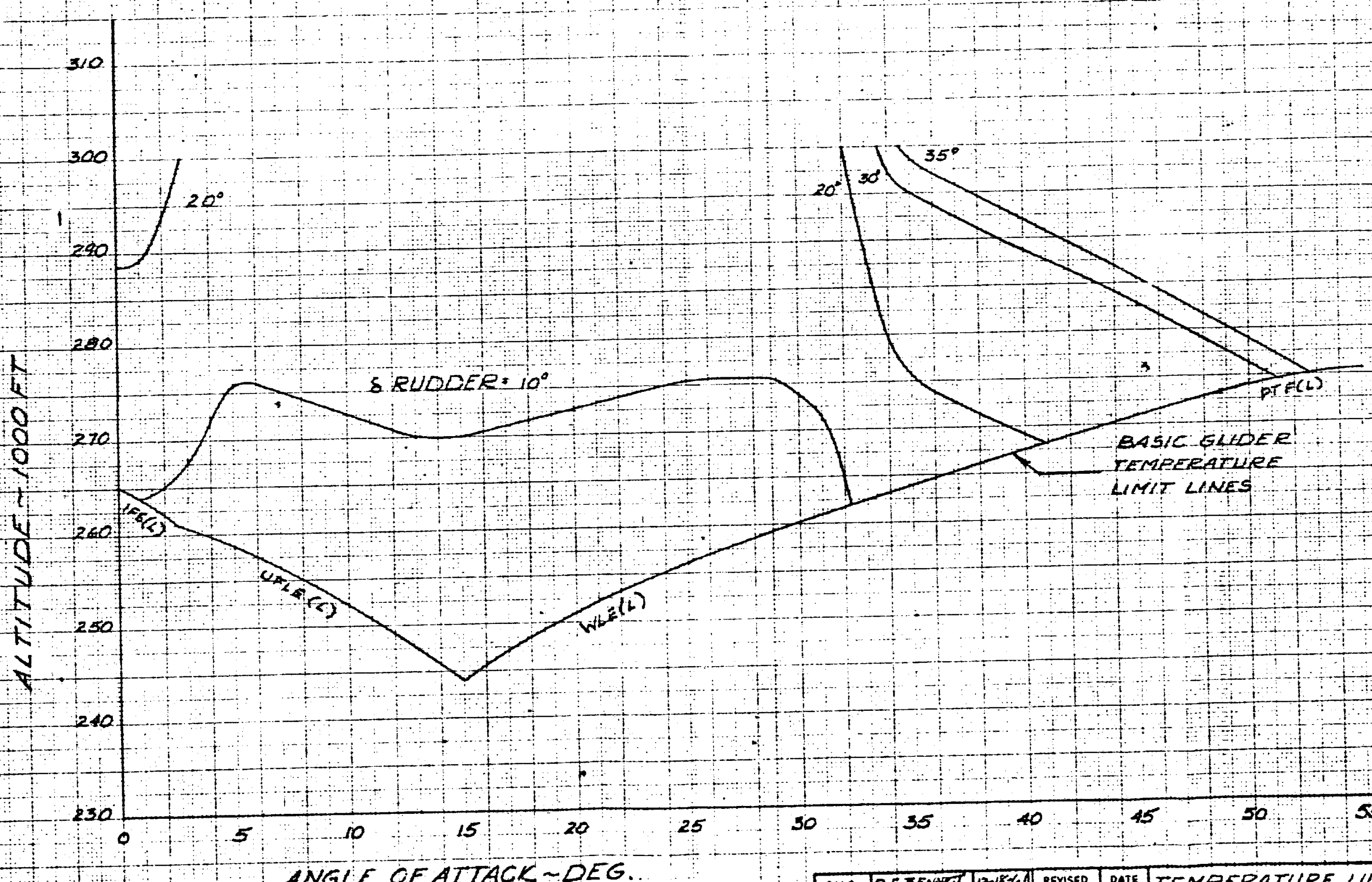

CALC	D.E. BENNETT	12-18-61	REVISED	DATE	TEMPERATURE LIMIT ALTITUDES -RUDDERS V=27,000 FPS
CHECK	ACT	12-15-61			
APPD					
APPD					

FIG. 5.29
844-2050D
D2-80065
PAGE 5.32

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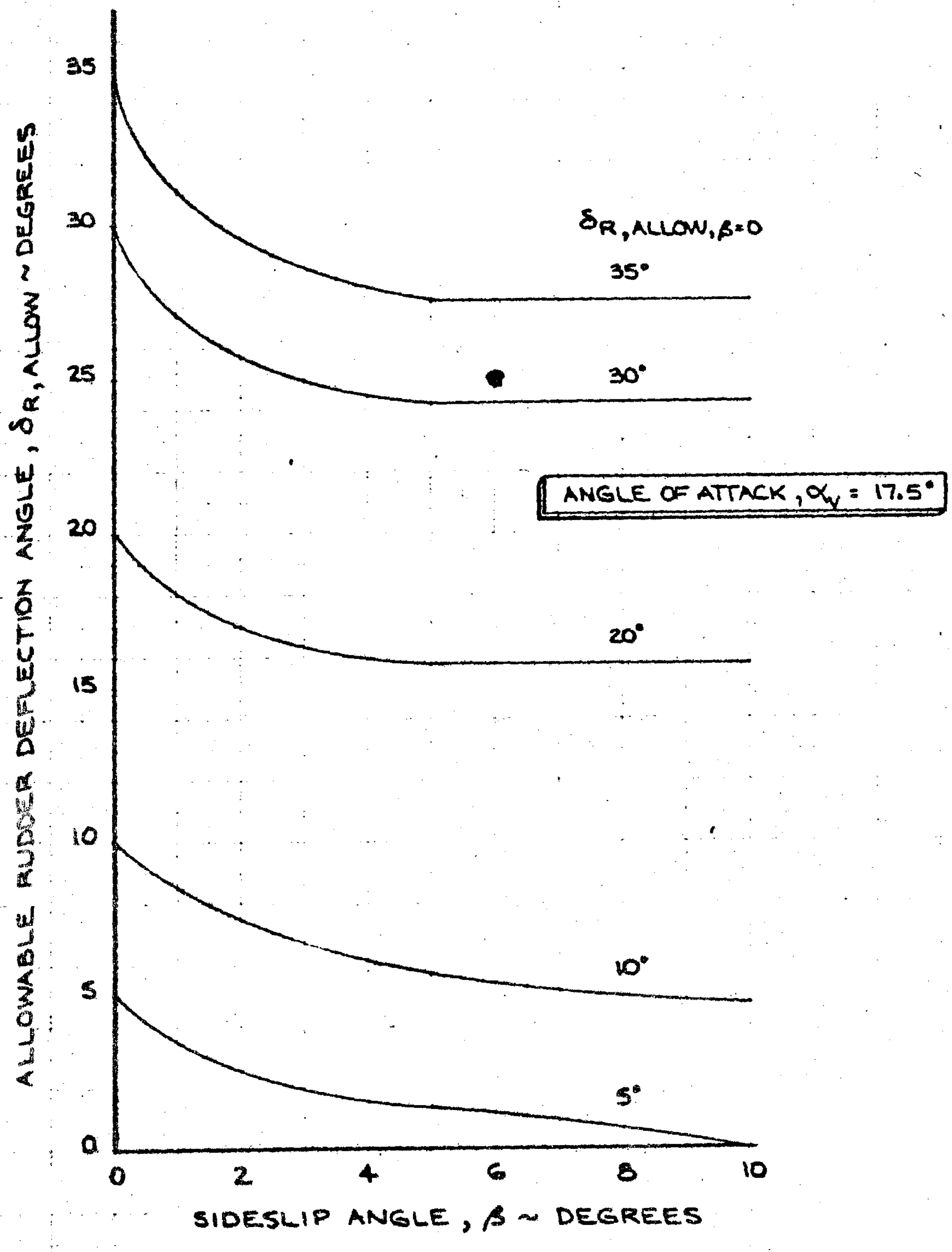

FIG. 5.30

CALC	TDB/BWE	12-19-61	REVISED	DATE	MAXIMUM ALLOWABLE RUDDER DEFLECTION	844-2050D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 5.33
APR						

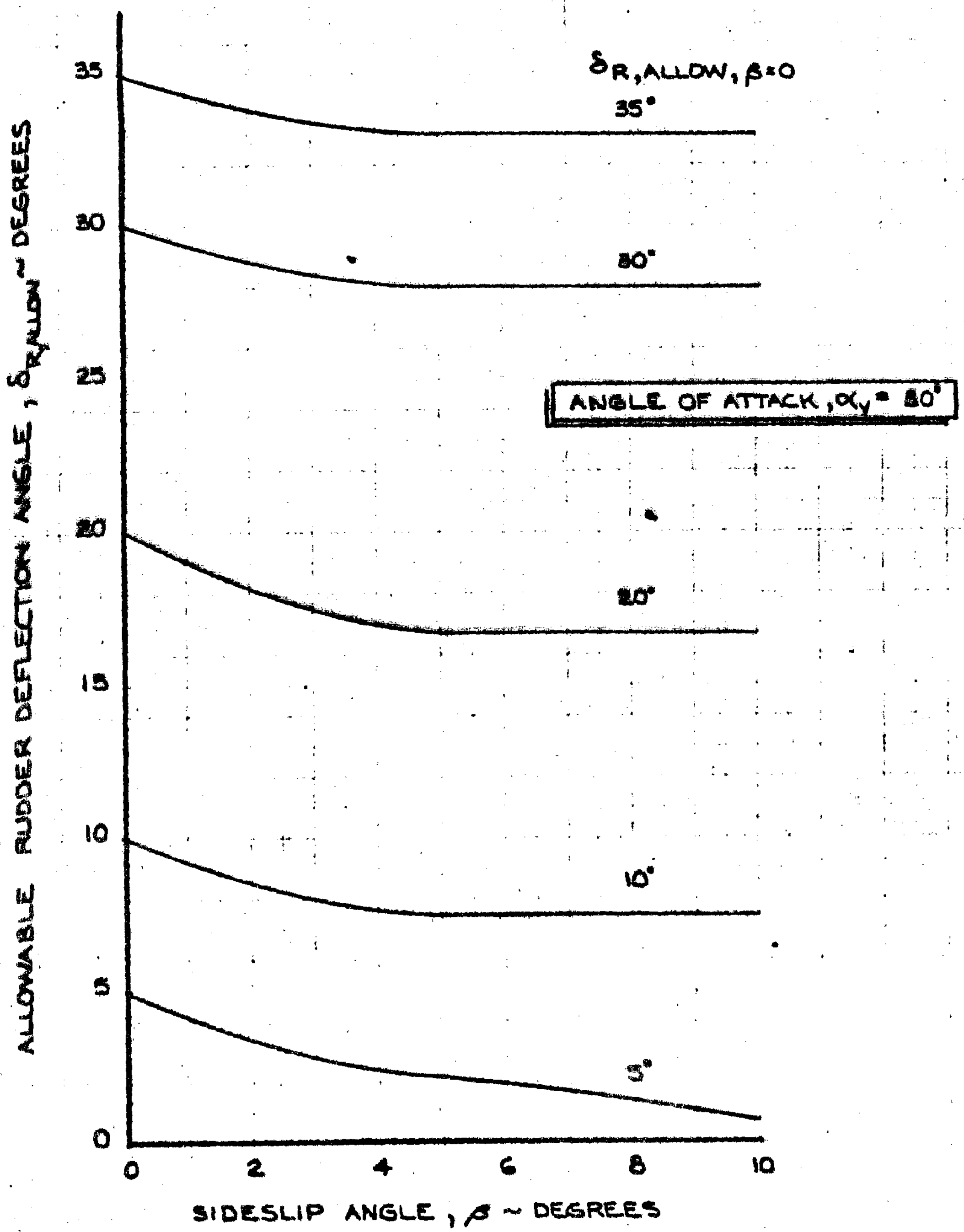

FIG. 5.31

CALC	TDB/BWR	12-19-61	REVISED	DATE	MAXIMUM ALLOWABLE RUDDER DEFLECTION	844-2050 D
CHECK	T. E.		12-20-61			D2-30065
APR						
APR					THE BOEING COMPANY	PAGE 5.34

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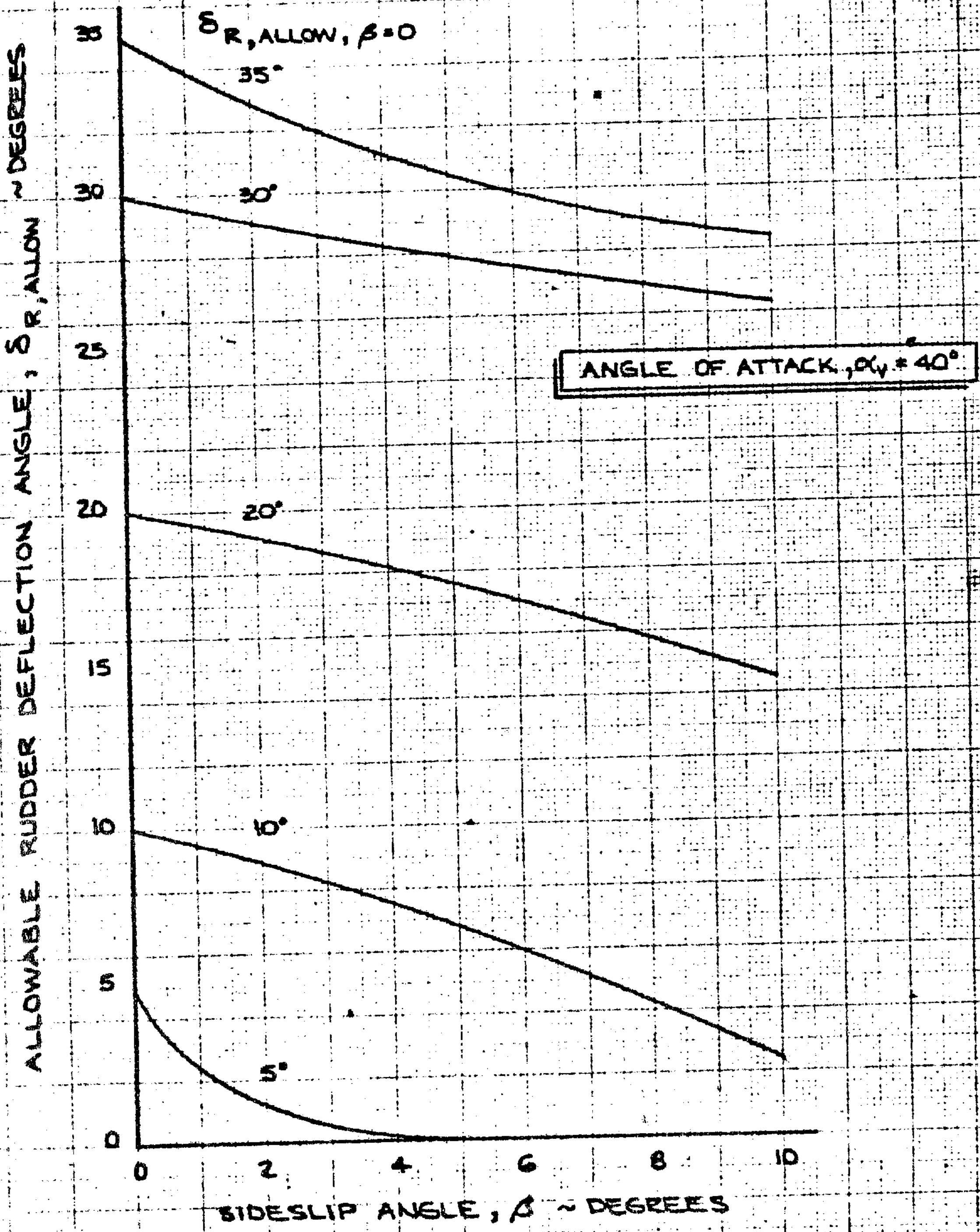

FIG. 5.32

			REVISED	DATE		
CALC	TDB/BWK	12-19-61			MAXIMUM ALLOWABLE RUDDER DEFLECTION	844-2050D
CHECK	T.L.R.		12-20-1			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 5.35

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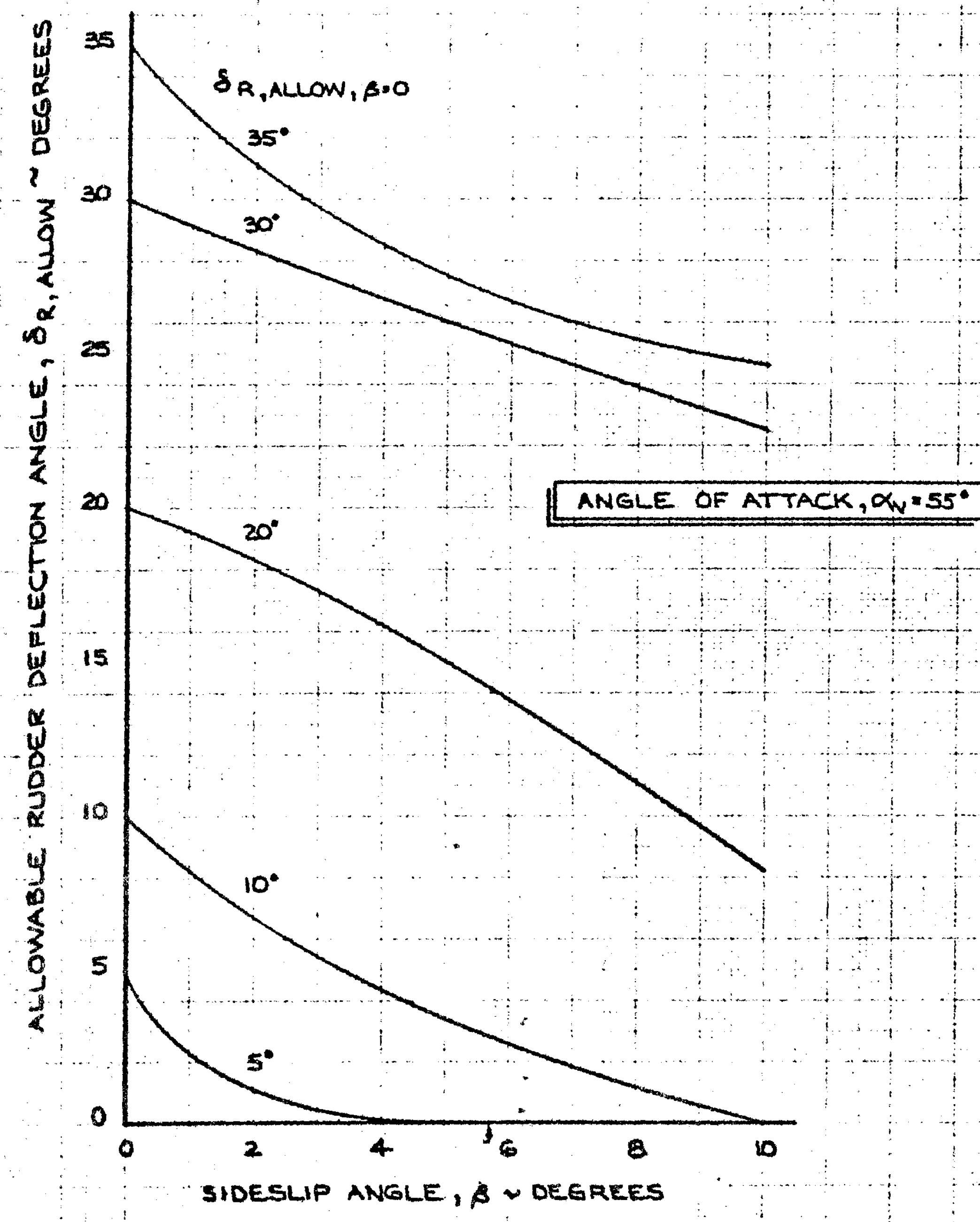

FIG. 5.33

CALC	TDB/BWR	12-19-61	REVISED	DATE	MAXIMUM ALLOWABLE RUDDER DEFLECTION	844-2050D
CHECK	TLE		12-20-61			D2-80065
APR					THE BOEING COMPANY	PAGE 5.36
APR						

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6.0 GLIDER STATIC STABILITY AND CONTROL

The static stability and control aerodynamic characteristics and surface hinge moment characteristics for the Dyna Soar glider, model 844-2050 revision D are presented in the following sub sections. The data from Mach number of 22 and 250,000 feet altitude through low speed landing are based on wind tunnel data. Modifications to these data were required to account for configuration changes that occurred on the last revision to the glider configuration.

Most of the data presented are for the rigid glider. Effects of thermal deformation on longitudinal stability and control are presented at hypersonic speeds. Only limited data on the aeroelastic glider are presented. These data are shown in Section 8. In general, the effects of thermal deformation and aeroelasticity are small. Additional work is currently in progress to better define these characteristics. These data will be presented in future revisions to this document.

Some limited data are also presented on longitudinal stability and control at extreme altitudes at near orbital velocity. Data are presented at altitudes to 500,000 feet where free molecular flow was assumed. These data are based on the limited theory available and maybe subject to significant errors, particularly at the intermediate altitudes around 350,000 feet.

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6.1 LONGITUDINAL STABILITY AND CONTROL

Presented in this section are the static longitudinal stability parameters of the Dyna-Soar glider configuration 844-2050 D over the Mach range from landing speed to high hypersonic. Longitudinal stability and elevon effectiveness are defined by normal force and pitching moment coefficients presented at the nominal center of gravity location of 44% of the mean aerodynamic chord and water line 124.

At hypersonic speeds, the glider is subject to thermal deformation produced by the flight temperature environment. Data are presented for the resulting configuration and are identified as "hot shape".

All data presented in this section are representative of the rigid glider. Aeroelastic effects have been determined and are included in Section 8.0.

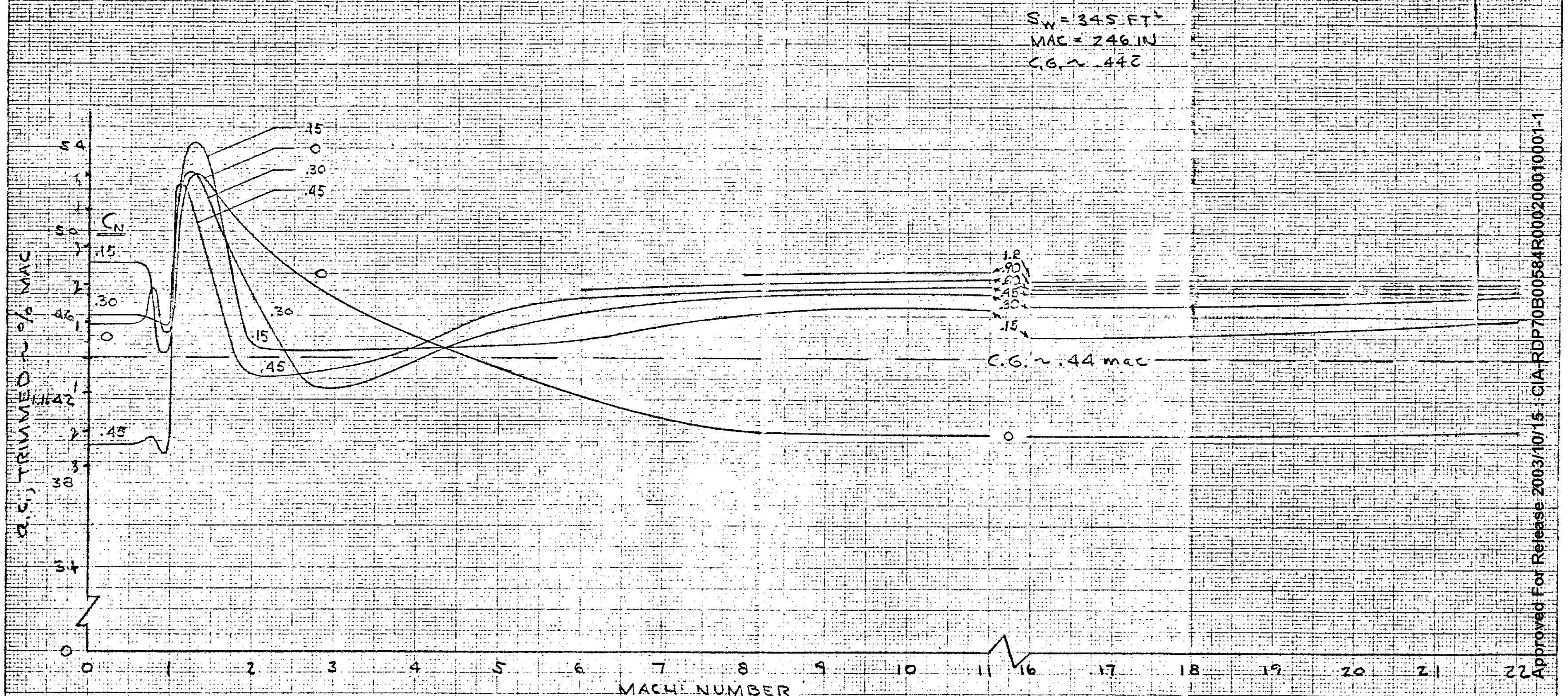
Longitudinal stability and elevon effectiveness over the Mach range are summarized in the following Figures; (6.1) trimmed aerodynamic center, (6.2) normal force curve slope, (6.3) pitching moment and angle of attack at zero normal force, (6.4) elevon required to trim, and (6.5) elevon effectiveness.

12-20-1

DYNA SOAR

MODEL 844-2050D

RIGID



CALC	EJ H/JLF	11/9/1	REVISED	DATE
CHECK			GDK	12-15-61
APPD				12-2?-?
APPD				

AERODYNAMIC CENTER
LONGITUDINAL

FIG. 6.1
844-2050D
D2-80065
PAGE 6.3

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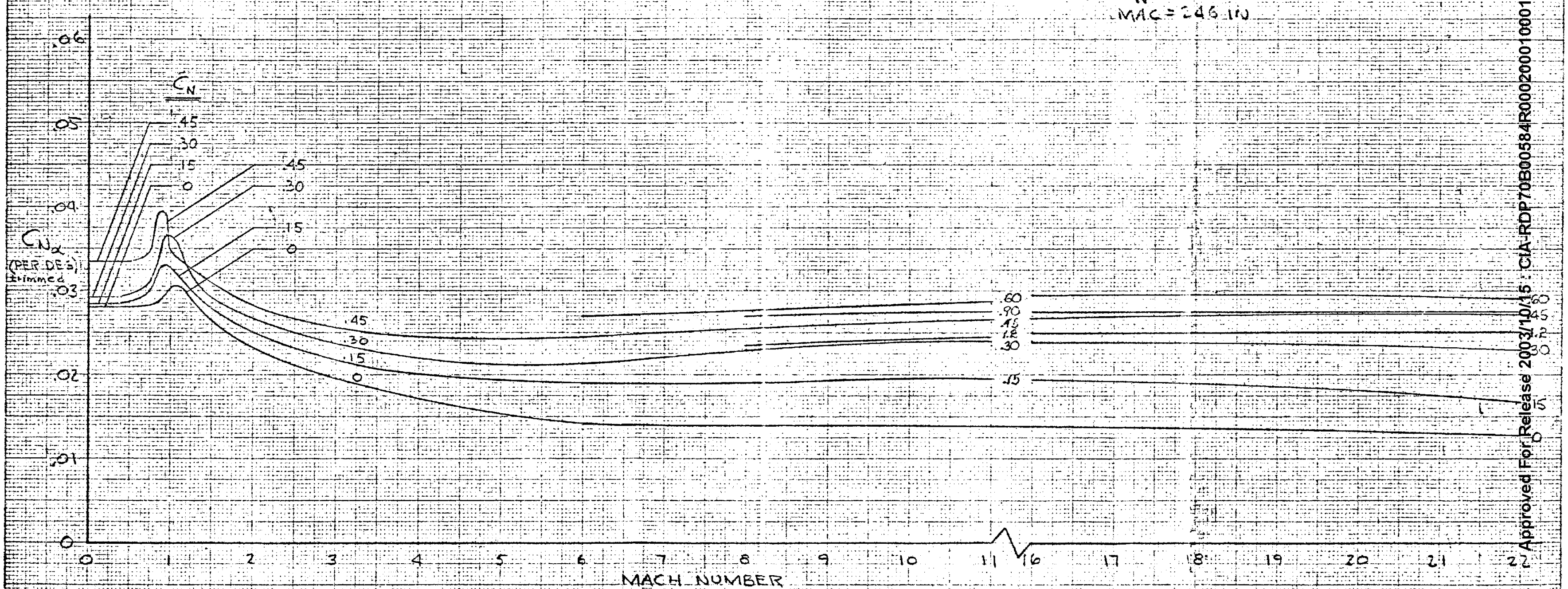
DYNA SOAR

MODEL 844-2050 D

RIGID

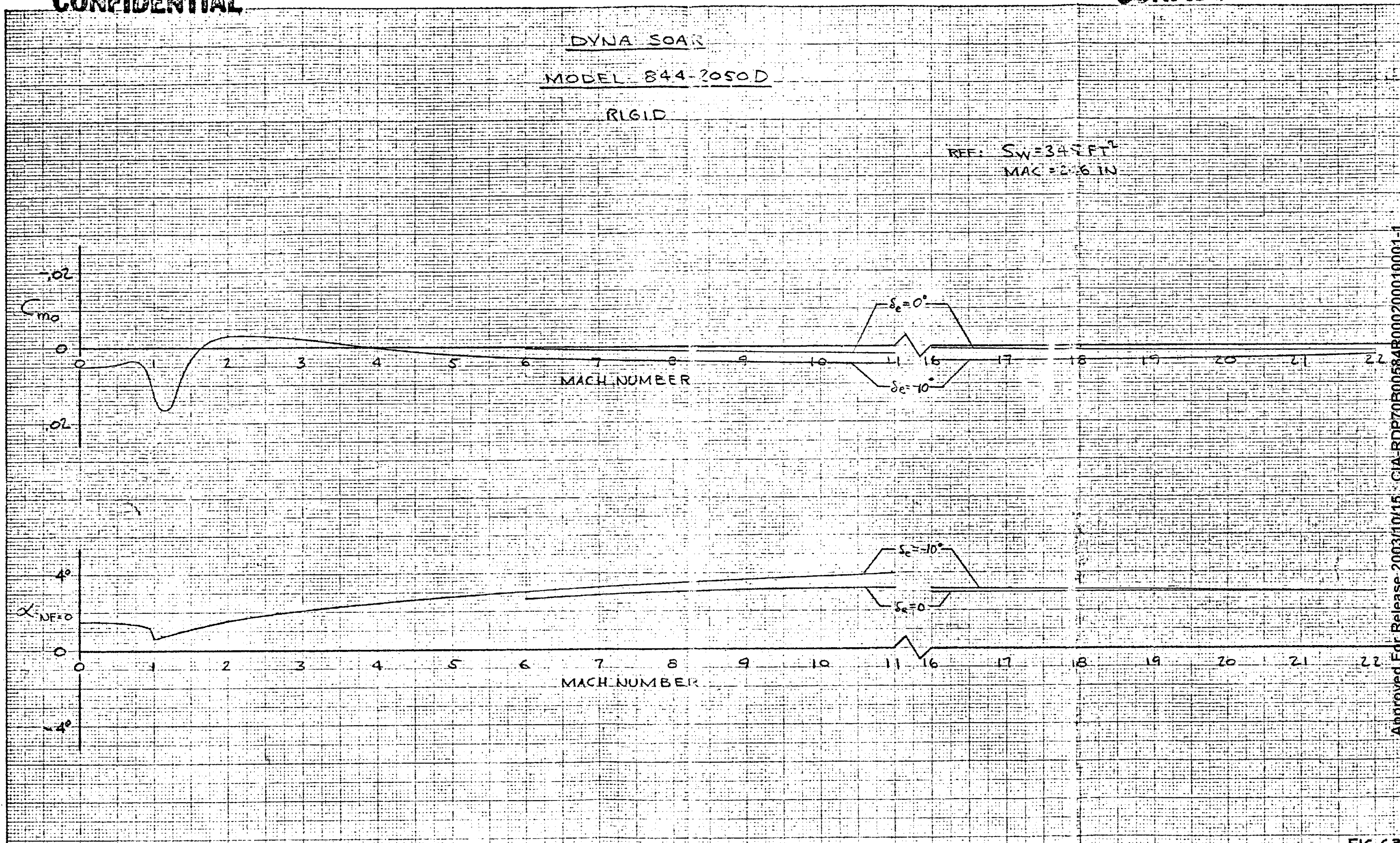
REF: $S_W = 3.15\ FT^2$
MAC = 246 IN



CALC	EJH/JLF	11/9/61	REVISED	DATE	TRIMMED NORMAL FORCE SLOPE	FIG. 6.2 844-2050D
CHECK			GDK	12-15-61		D2-80065
APPD				12-22-61		PAGE 6.4
APPD						

US 4041 7000

Approved For Release 2003/10/15 : CIA-RDP70B00584R000200010001-1



CALC	EJH/JLF	11/10/61	REVISED	DATE	ANGLE OF ATTACK AND PITCHING MOMENT AT ZERO NORMAL FORCE	FIG. 6.3
CHECK			12-?-1			844-2050D
APPD						D2-80065
APPD						PAGE 65

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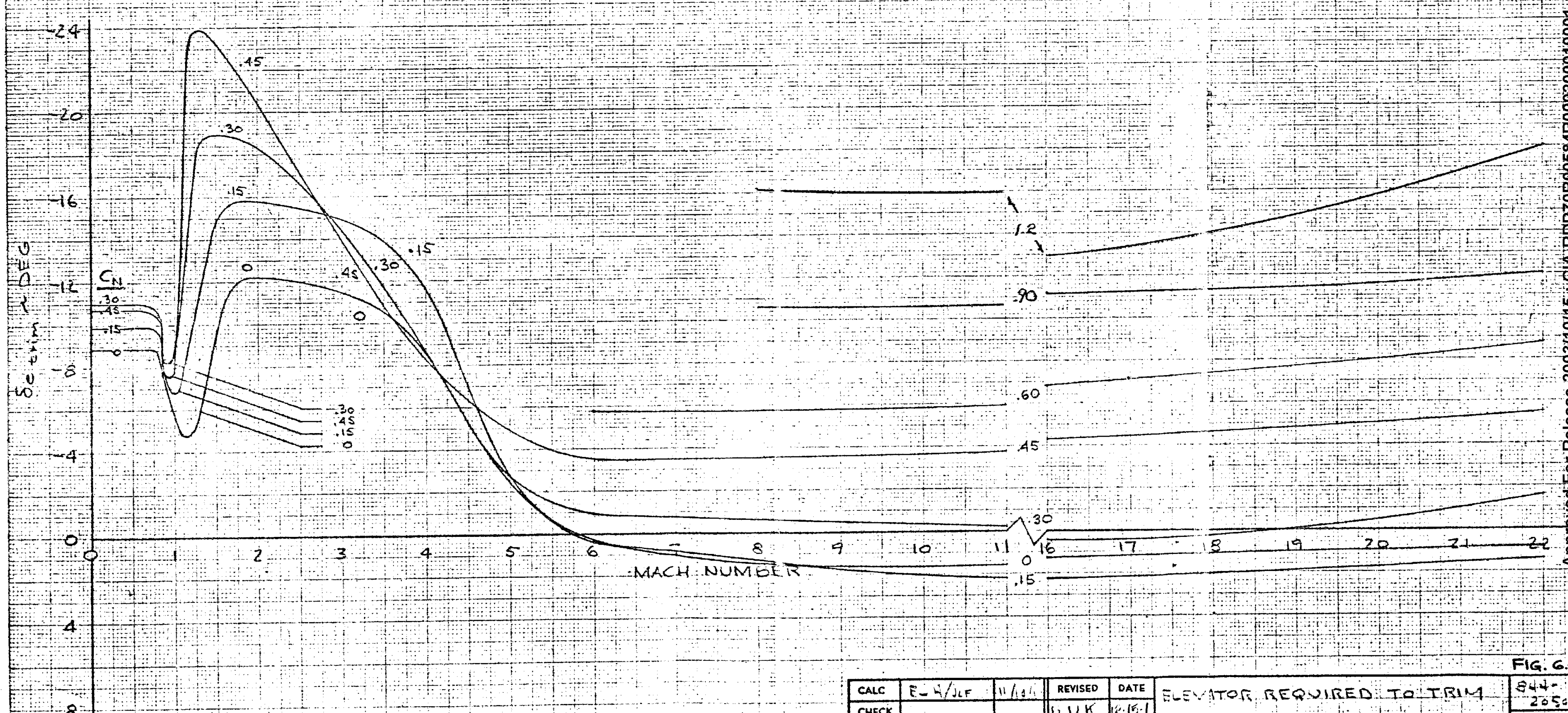
DYNA SOAR

MODEL 844-2050D

RIGID

REF: S_W = 345 FT²
MAC = 246 IN
C.G. ≈ .44 c̄



CALC	E.H./JLF	11/1/61	REVISED	DATE	ELEVATOR REQUIRED TO TRIM	844-2050D
CHECK			DUK	12-15-61		D2-80065
APPD						PAGE 6.6
APPD						

FIG. 6.4

80

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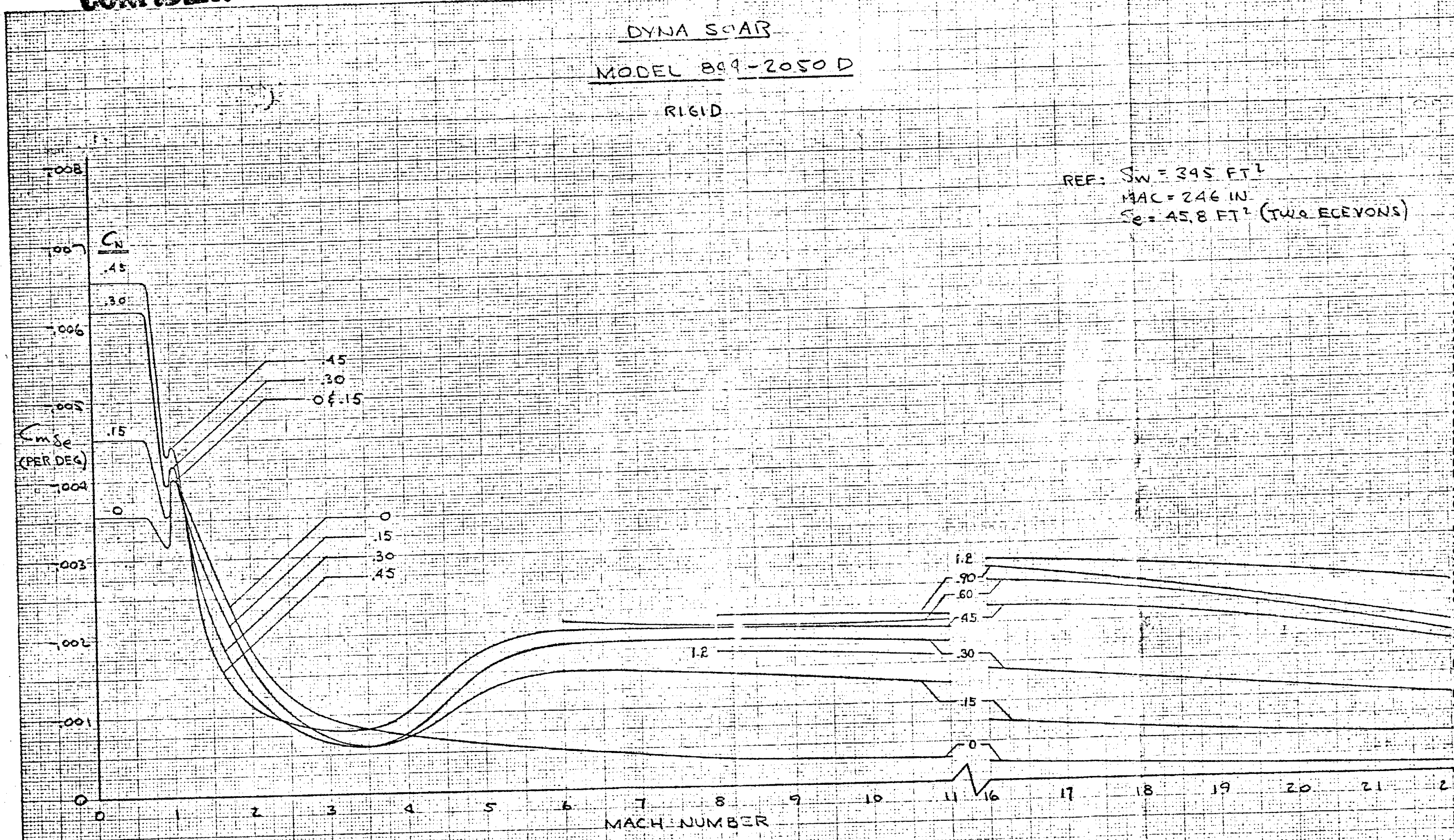

FIG. 6.5

CALC	EJH/JCF	11/17/1	REVISED	DATE	ELEVON EFFECTIVENESS	844-2050D
CHECK						D2-80065
APPD						PAGE 6.7
APPD						

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6.1.1 LANDING SPEED

Longitudinal stability and elevon effectiveness plots are presented in Figures 6.6 for the glider at a Mach number typical of landing speed. The trimmed normal force coefficients available at any angle of attack at landing speed are shown in Figure 6.7. These data were determined from test 685 in the Boeing Transonic Wind Tunnel and modified to the revision D configuration through the application of data from Boeing Transonic test 682.

The change in stability and control effectiveness with landing gear extended in the presence of a ground plane is shown in Figure 6.6. This effect was determined from wind tunnel tests in the Boeing Transonic Wind Tunnel on a similar configuration and this data was used to estimate the effect for the present configuration.

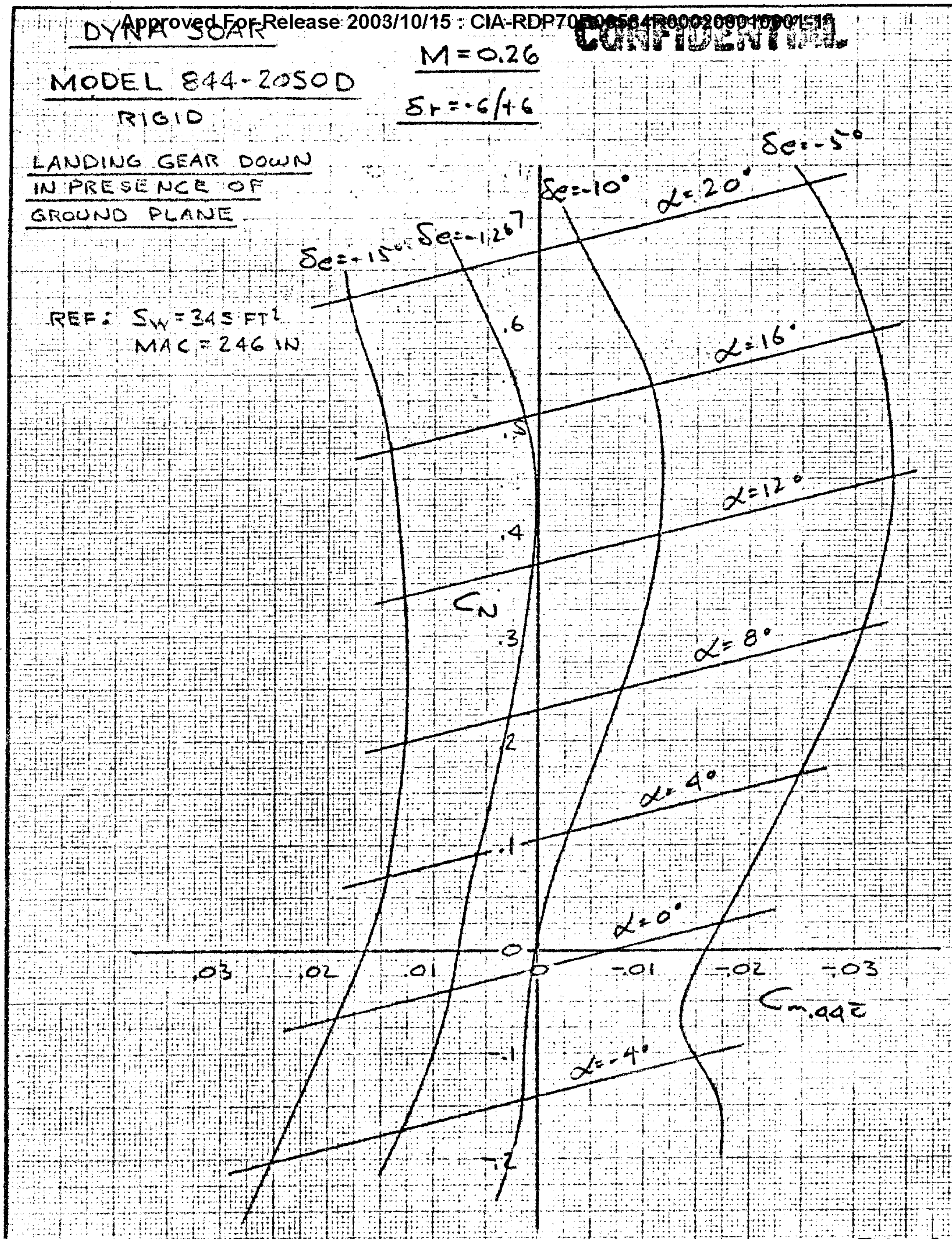

FIG. 6.6

CALC	EJH	11/17/1	REVISED	DATE	LONGITUDINAL STABILITY M=0.26 LANDING GEAR DOWN IN PRESENCE OF GROUND PLANE	844-2050D
CHECK			12-20-1			D2-80065
APR						
APR					BOEING AIRPLANE COMPANY	PAGE 69

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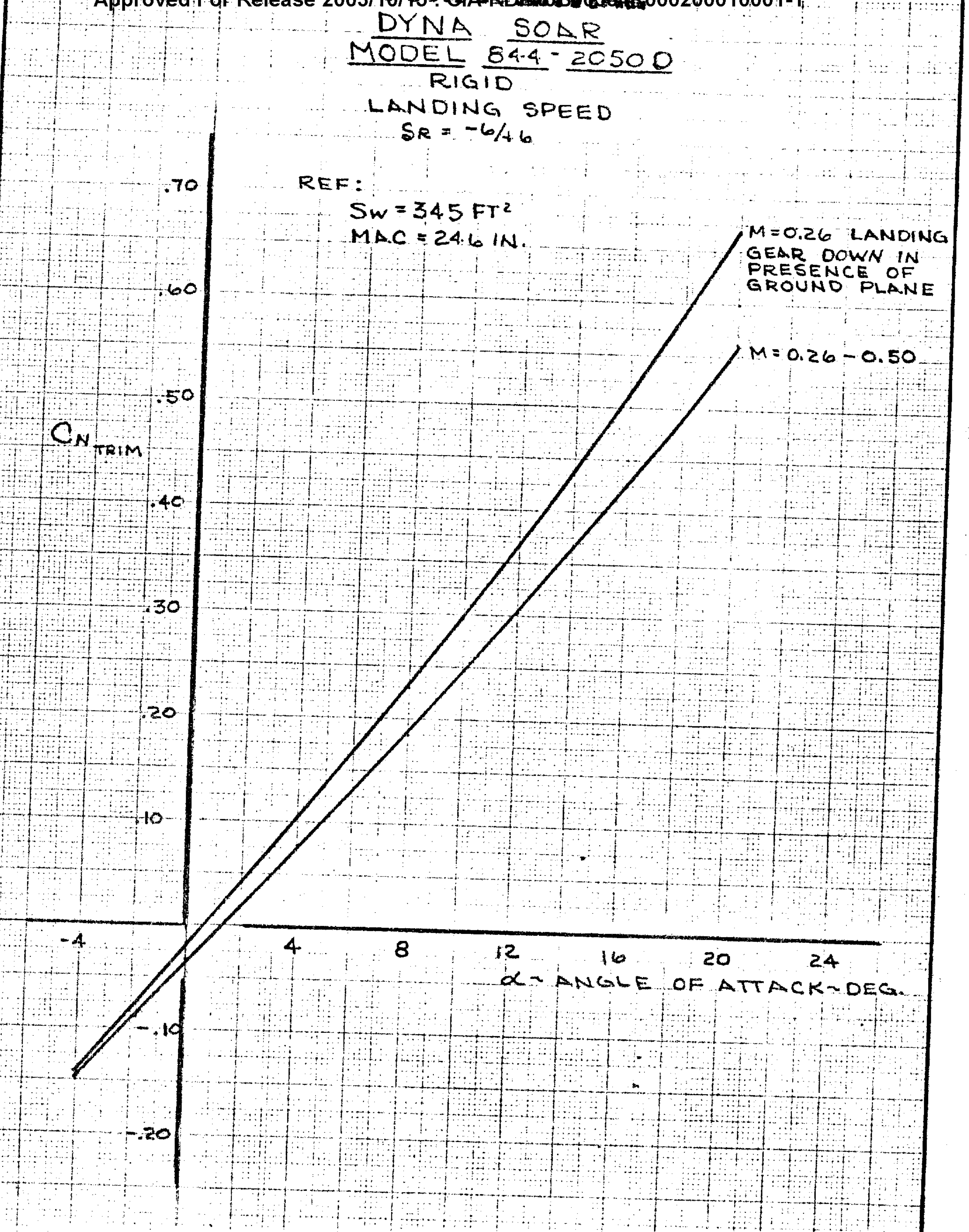

FIG. 6.7

CALC	CLAAR	12-18-1	REVISED	DATE	TRIMMED NORMAL FORCE LANDING SPEED	844-2050D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.10
APR						

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6.1.2 SUBSONIC - TRANSONIC SPEED

The longitudinal static stability and control effectiveness characteristics for the model 844-2050 revision D glider are shown in Figures 6.8 through 6.12, for the subsonic - transonic speed range. The corresponding trimmed normal force coefficients available at any angle of attack are shown in Figure 6.17. The data are based on Boeing Transonic Wind Tunnel tests 672 and 685 and modified by data from Boeing Transonic test 682.

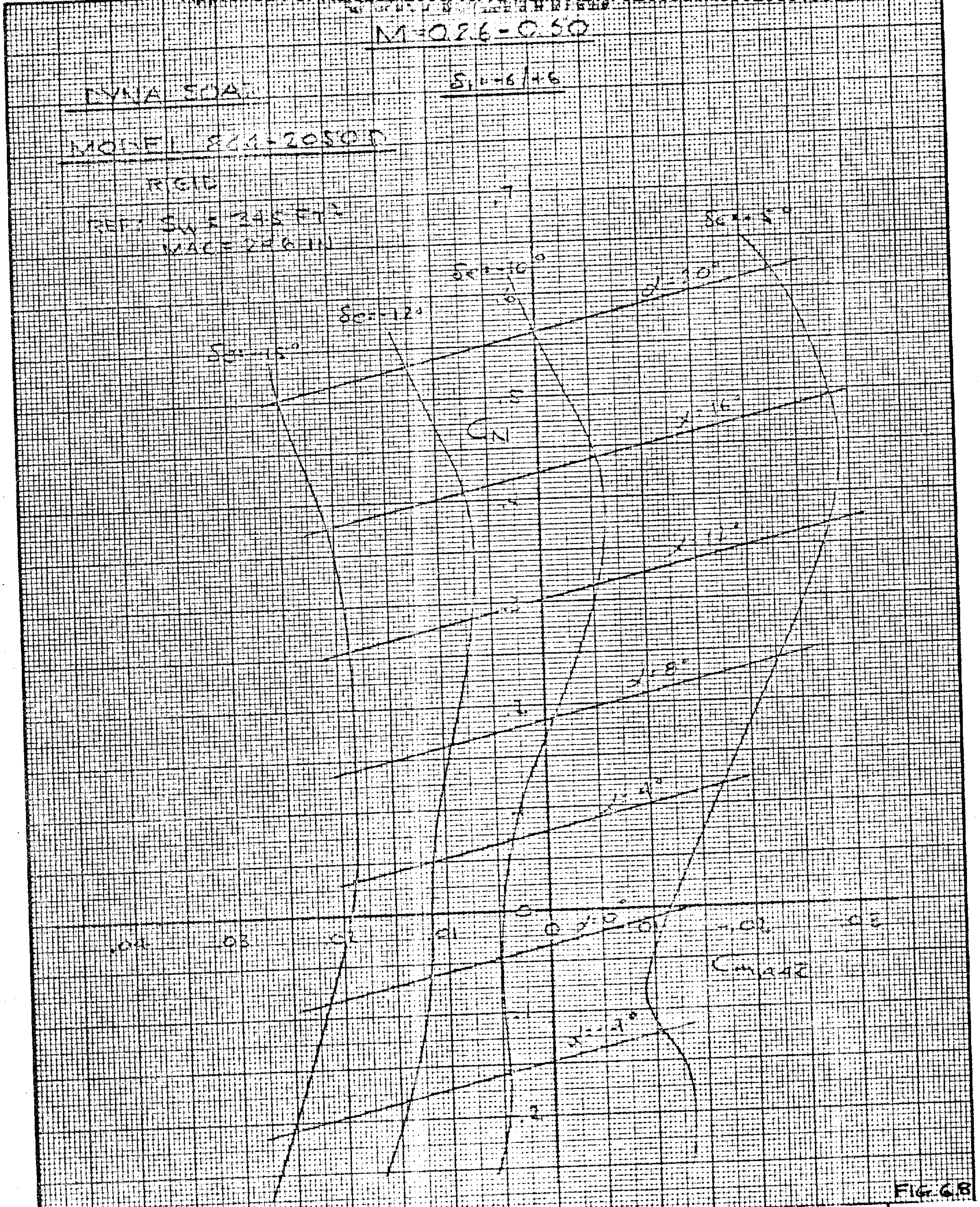

FIG. 6.8

CALC	EJH	11/1/61	REVISED	DATE	LONGITUDINAL STABILITY M=0.26-0.50
CHECK					
APR					THE BOEING COMPANY
APR					

844-2050D

PAGE 6.12

U3 4013 8000

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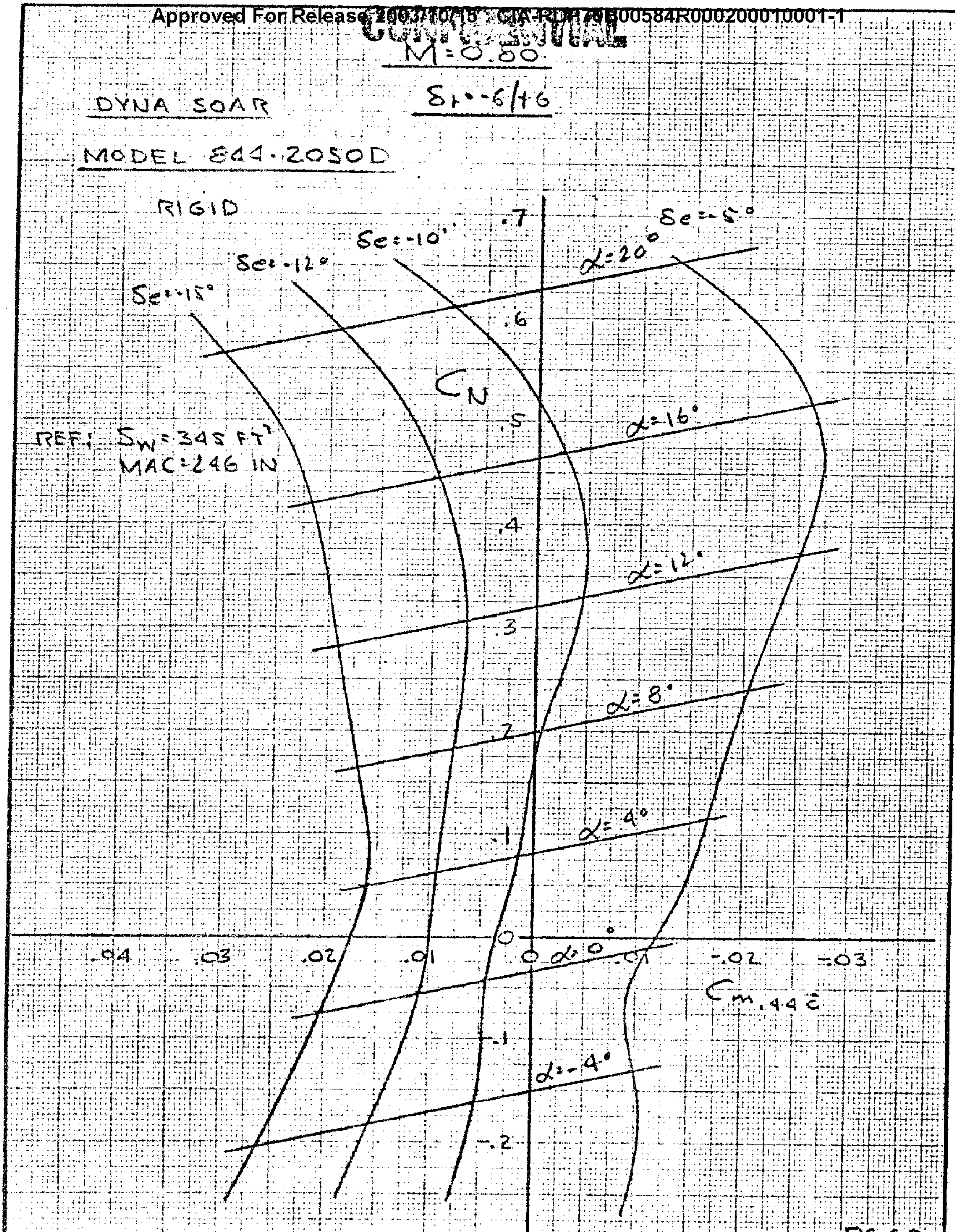

FIG. 6.9

CALC	EJH	11/3/1	REVISED	DATE	LONGITUDINAL STABILITY M=0.80	844-2050D
CHECK						D2-80065
APR					BOEING AIRPLANE COMPANY	PAGE 6.13
APR						

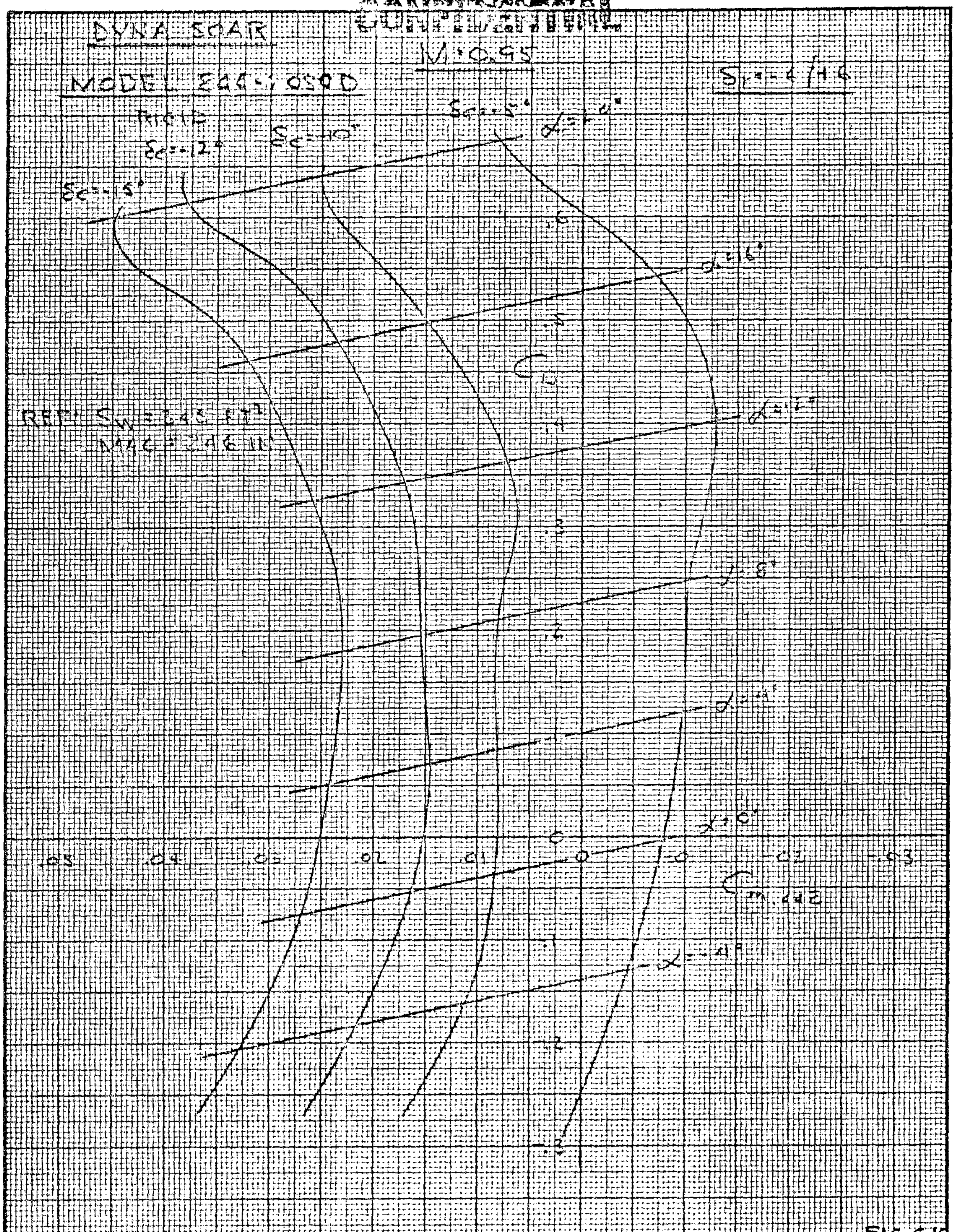

FIG. 6.10

CALC	EJH	11/3/1	REVISED	DATE	LONGITUDINAL STABILITY M=0.95	844-2050D
CHECK						
APR						
APR					THE BOEING COMPANY	PAGE 6.14

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W,B,V,VBE,

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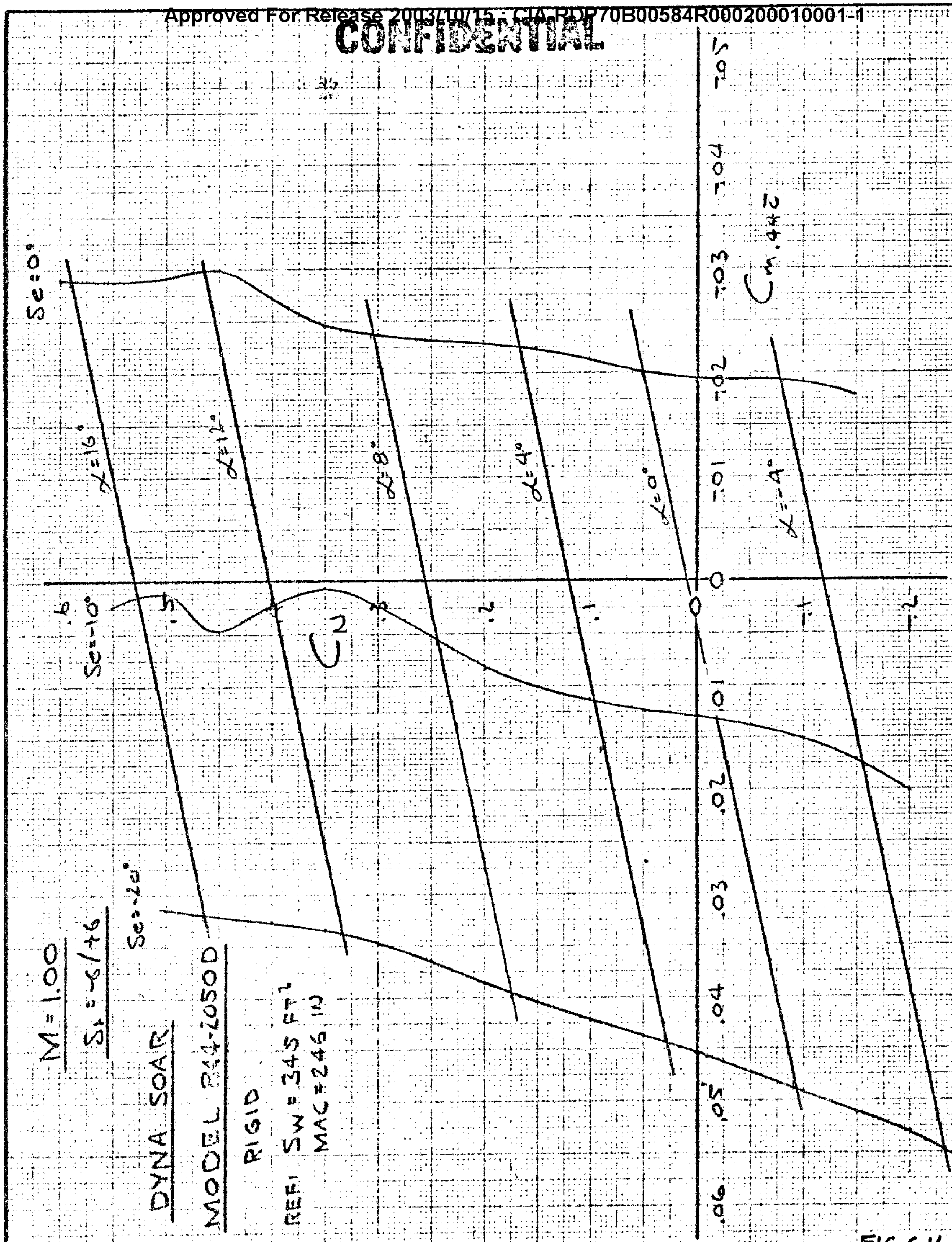

FIG. 6.11

CALC	EJH	11/8/61	REVISED	DATE	LONGITUDINAL STABILITY M=1.00
CHECK					
APR					
APR					THE BOEING COMPANY

844-2050D

D2-80065

PAGE 6.15

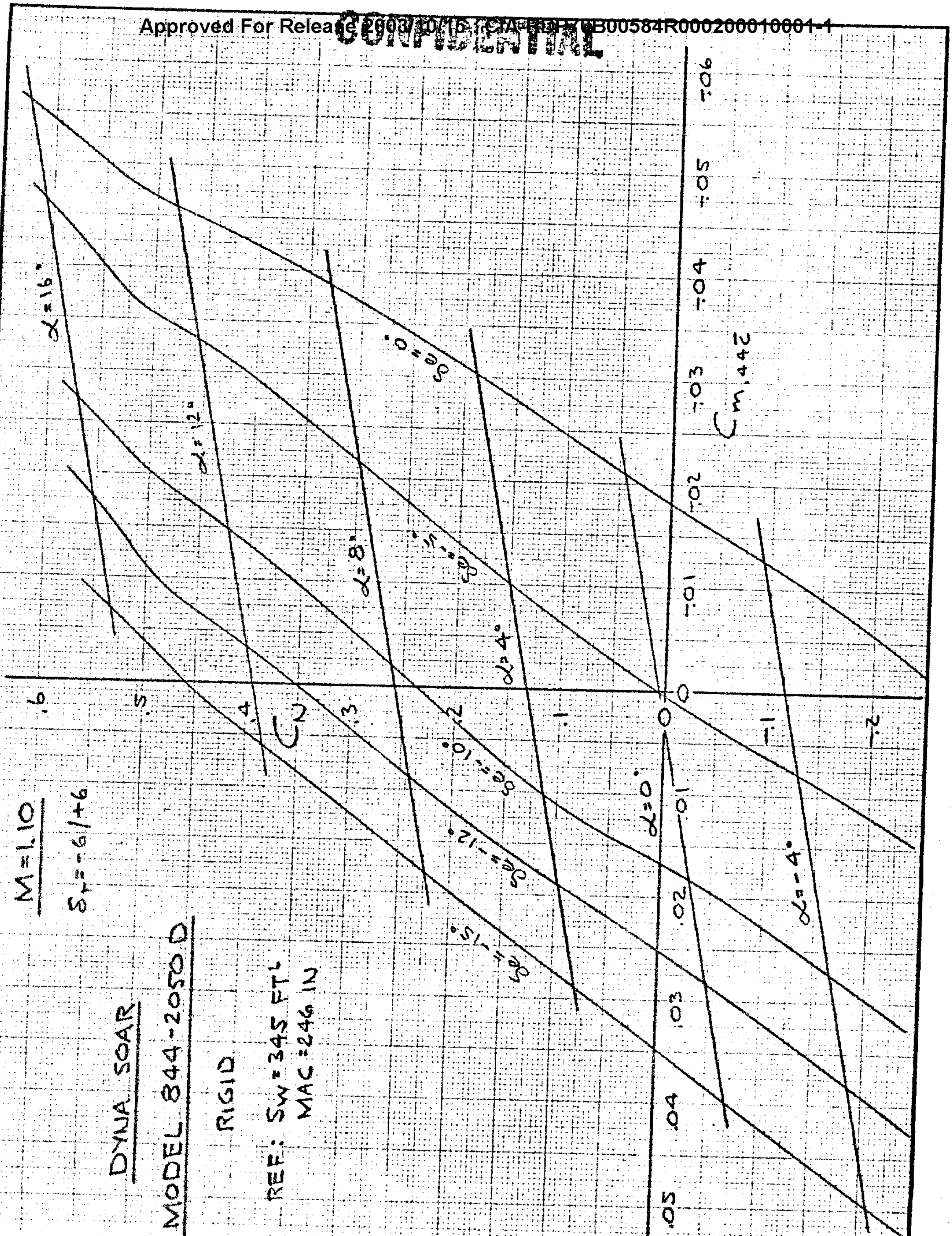

FIG. 6.12

CALC	EJH	11/2/1	REVISED	DATE	LONGITUDINAL STABILITY M=1.10	844-2050D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.16

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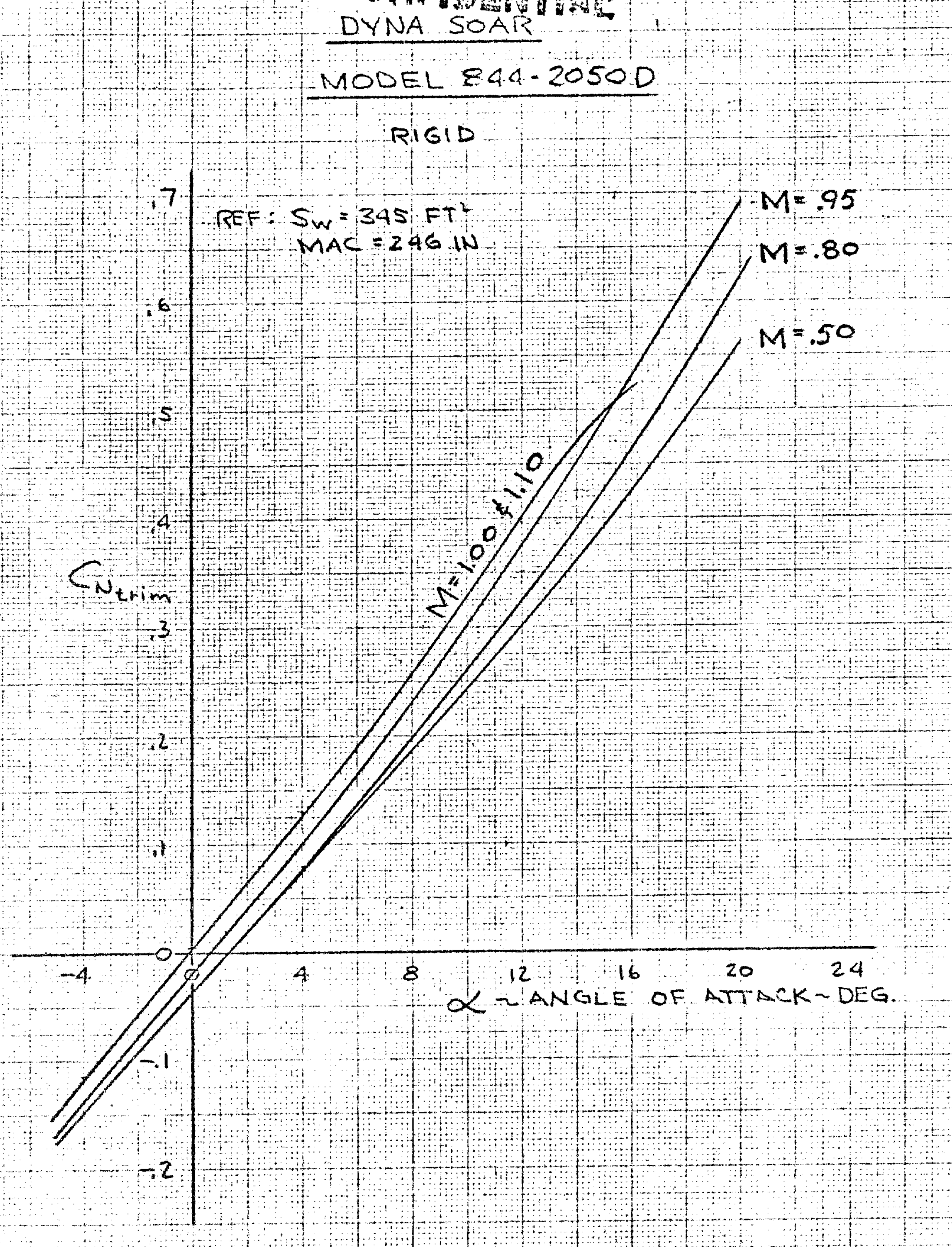

FIG. 6.13

CALC	EJH	11/9/61	REVISED	DATE	TRIMMED NORMAL FORCE
CHECK					SUBSONIC - TRANSONIC
APR					THE BOEING COMPANY
APR					

844-2050D

D2-80065

PAGE 6.17

US 4013 8000

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6.1.3 SUPERSONIC SPEED

The longitudinal static stability and control characteristics for the model 844-2050 revision D glider configuration are shown in Figures 6.14 through 6.16 for supersonic speeds. The corresponding normal force coefficients available at any angle of attack are shown in Figure 6.17 . These data are based on Boeing Supersonic Wind Tunnel tests 105 and 113.

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DYNA SOAR
MODEL 844-2050D
RIGID

REF: $S_W = 345\ FT^2$
MAC = 246 IN

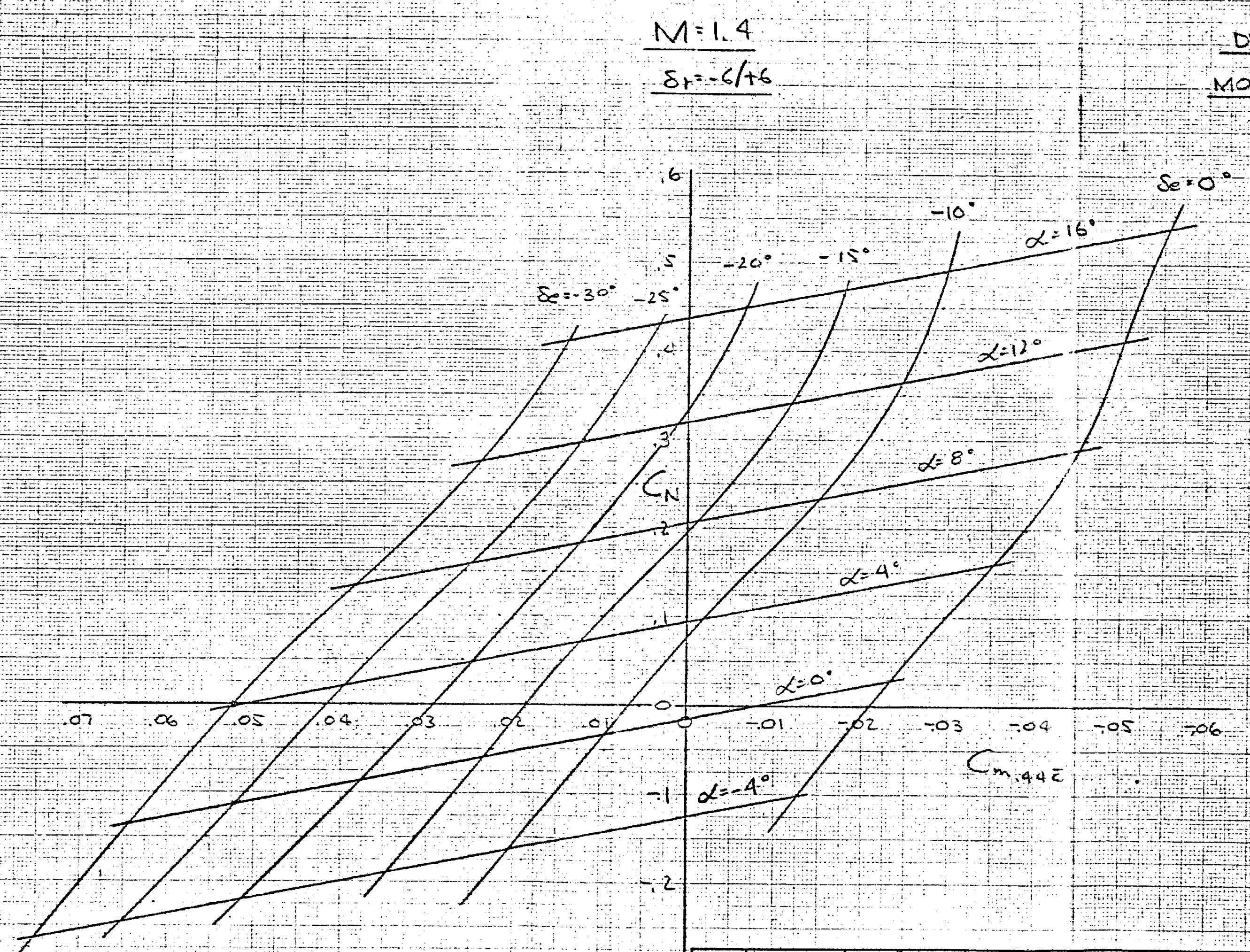

FIG. 6.14

CALC	EJH	11/7/1	REVISED	DATE
CHECK				
APPD				
APPD				

LONGITUDINAL STABILITY
M = 1.40

844-2050D

PAGE 6.19

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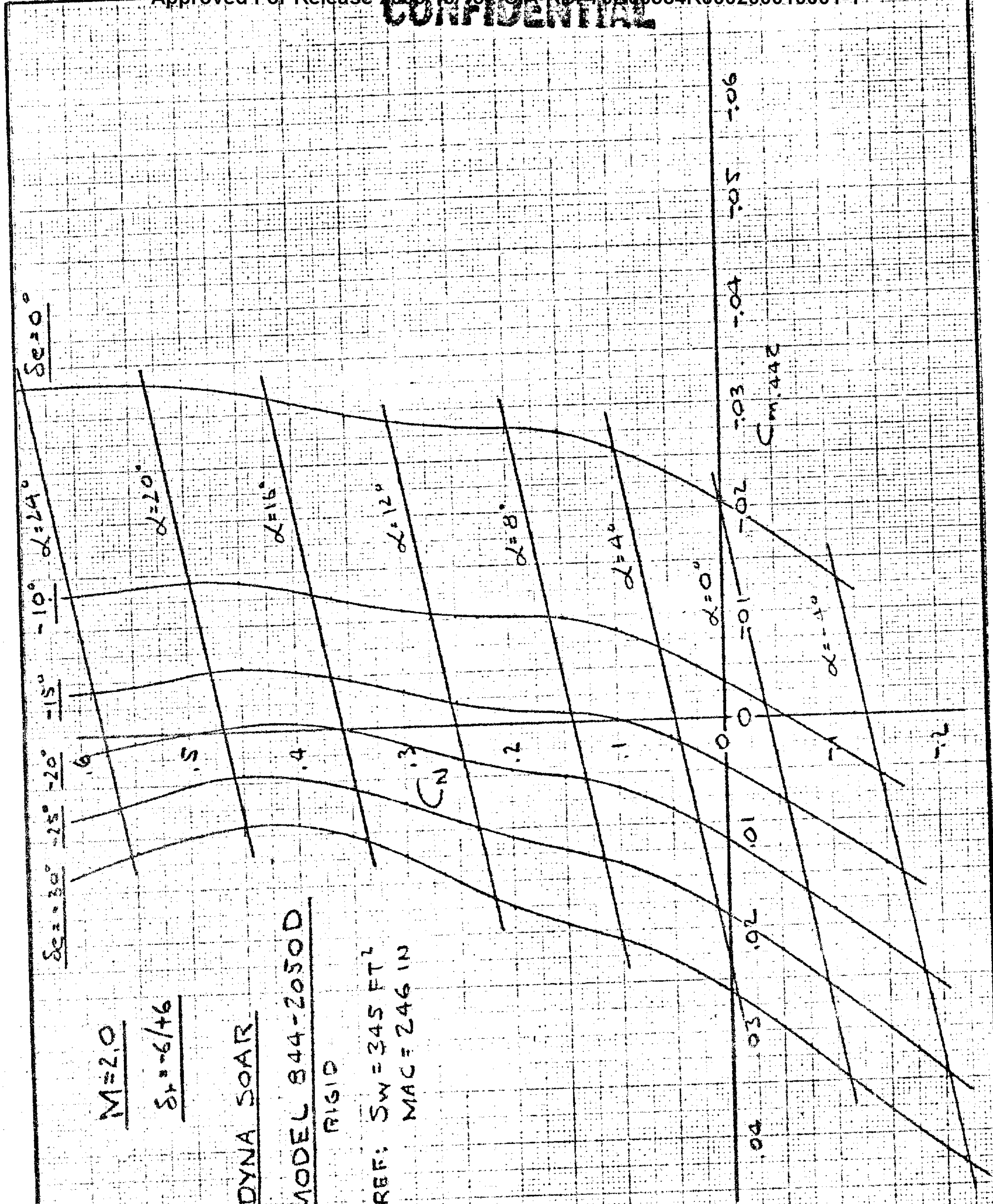

FIG. 6.15

CALC	EJH	11/7/1	REVISED	DATE	LONGITUDINAL STABILITY M = 2.0	844-2050D
CHECK			12-2-1			D2-80065
APR					THE BOEING COMPANY	PAGE 6.20
APR						

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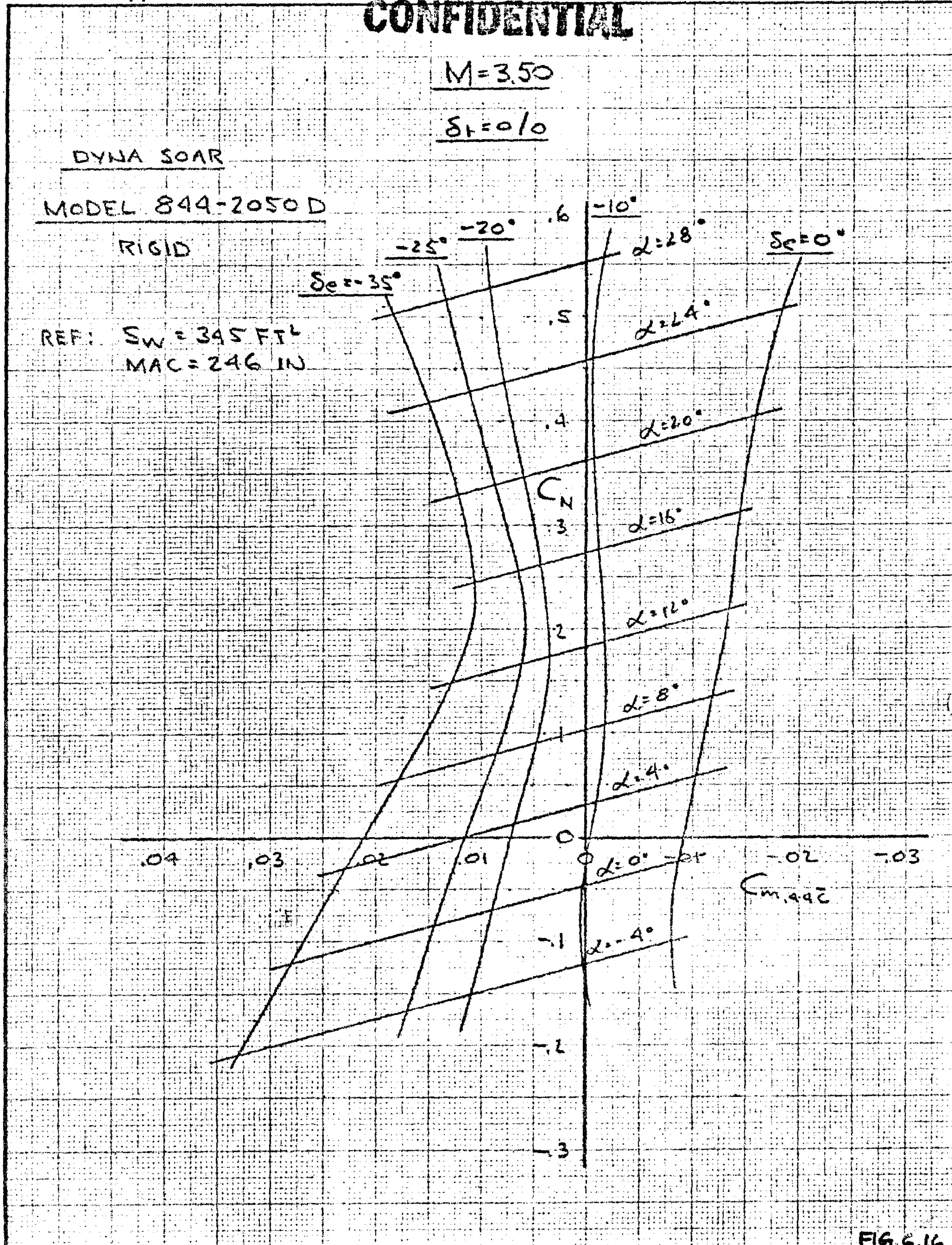

FIG. 6.16

CALC	EJH	11/21/61	REVISED	DATE	LONGITUDINAL STABILITY M=3.50	844-2050D
CHECK			12-2-?			D2-80065
APR					THE BOEING COMPANY	PAGE 6.21
APR						

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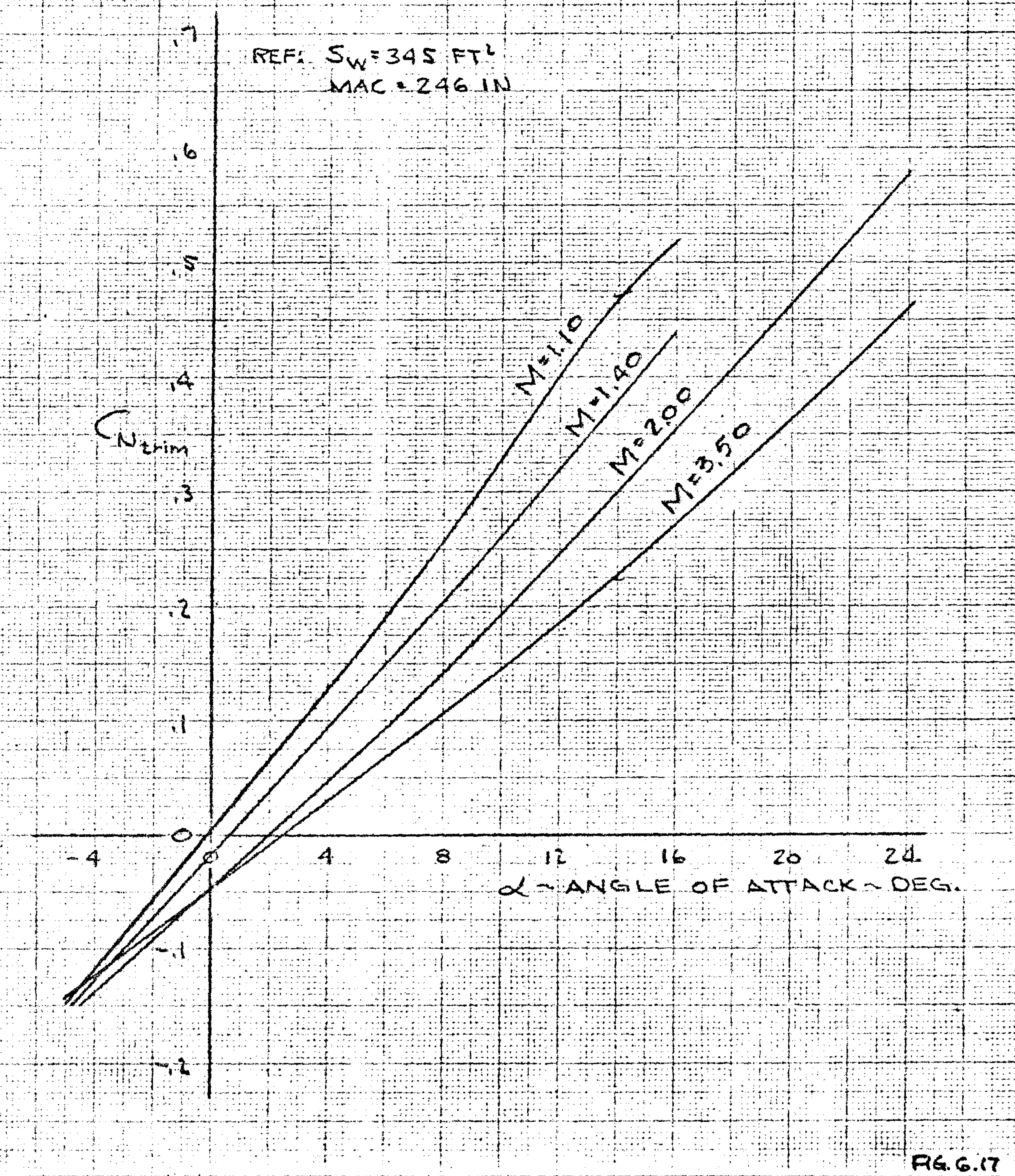
DYNA SOAR

MODEL 844-2050D

RIGID



W,B,,VBE7

FIG. 6.17

CALC	EJH	4/1/61	REVISED	DATE	TRIMMED NORMAL FORCE	844-2050D
CHECK					SUPERSONIC	
APR						D2-80065
APR					THE BOEING COMPANY	PAGE 6.22

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6.1.4 HYPERSONIC SPEED

Longitudinal static stability and control characteristics for model 844-2050 D glider configuration are shown in Figures 6.18 through 6.62 for hypersonic speeds. Curves of longitudinal stability, longitudinal aerodynamic center, trim requirements, trimmed normal force and control effectiveness are shown at individual Mach numbers of 6, 8, 9, 11, 16 and 22 with two Reynolds numbers considered at a Mach number of 9. Figures are based on modified test data obtained at Jet Propulsion Laboratory 21" Hypersonic Wind Tunnel (M = 6, 9, 11), Arnold Center Tunnel B (M = 8) and Boeing Hot Shot Wind Tunnel (M = 16, 22). Theoretical corrections to test data have been made at low angles of attack to account for configuration modifications consisting of an upper aft body flare and a thicker vertical tail.

Low angle of attack data ($\alpha < 20°$) at M = 6, 9, 11 and high angle of attack data ($\alpha > 20°$) at M = 16, 22 have been extrapolated on the basis of M = 8 data, previous wind tunnel tests of similar configurations and theoretical estimates.

Basic hypersonic test models were thermally deformed configurations ("hot shape") which had a 4 degree nose inclination as opposed to the cold 3 degree shape. Figures for both "hot" and "cold" configurations are shown for Mach numbers of 6, 8, and 9 with only "hot shape" shown for higher Mach numbers.

The continuous flow facilities at Mach numbers of 11 and below are capable of matching flight conditions and yield consistent data. At high Mach numbers "hot shot" data show a much higher degree of scatter. While the "hot shot" test conditions cannot duplicate flight enthalpy and slight conical nozzle effects are present, these deviations are negligible on stability and control characteristics in comparison to data scatter.

In the rarefied gas regime, curves are presented at intermediate altitudes between the "cold shape" continuum flow values at 250,000 feet and the free molecule values at 500,000 feet. These data are assumed to apply in the speed regime above 20,000 feet per second. The data shown at 250,000 feet altitude are from test data in the Boeing Hot Shot tunnel at a Mach number of 22. Free molecular flow was assumed to exist at 500,000 feet altitude. Full momentum transfer of the particles was assumed. The effect of re-emission was considered to be negligible. At intermediate altitudes the Knudsen number, which may be considered a similarity number for rarefied flows, was used to establish a rational interpolation. The free molecule values of pitching moment and normal force were approached as the Knudsen number became large. The incremental modification to the "cold shape" continuum data was obtained in the following manner:

6.1.4 HYPERSONIC SPEED (Cont'd)

$$\frac{K}{K+1}\left(\Delta C_M\right)_{CONT-FM} = \Delta C_M$$

$$\frac{K}{K+1}\left(\Delta C_N\right)_{CONT-FM} = \Delta C_N$$

WHERE $K = \frac{\lambda}{d}$

λ = MEAN FREE PATH

$d = \bar{c} \sin\alpha \quad \alpha \geq 15°$

$d = \tau_w \quad \alpha < 15°$

$\bar{c}$ = MEAN AERODYNAMIC CHORD

τ_w = WING THICKNESS

At altitudes up to 350,000 ft where significant continuum effects may still exist, a decrease in elevon effectiveness was considered. A thickening of the large hypersonic boundary layer as it expands around the upward deflected elevon will decrease the effective angle of expansion. By use of a computer program which numerically integrates the boundary layer equations, References 1 & 2, momentum thicknesses were obtained before and after the expansion. Loss in effectiveness was then obtained from the effective angle of expansion along the chord of the elevon in the form of $\frac{d\delta^*}{dx_1}$. Additional analytical and experimental work is continuing in this region of rarefied gas dynamics.

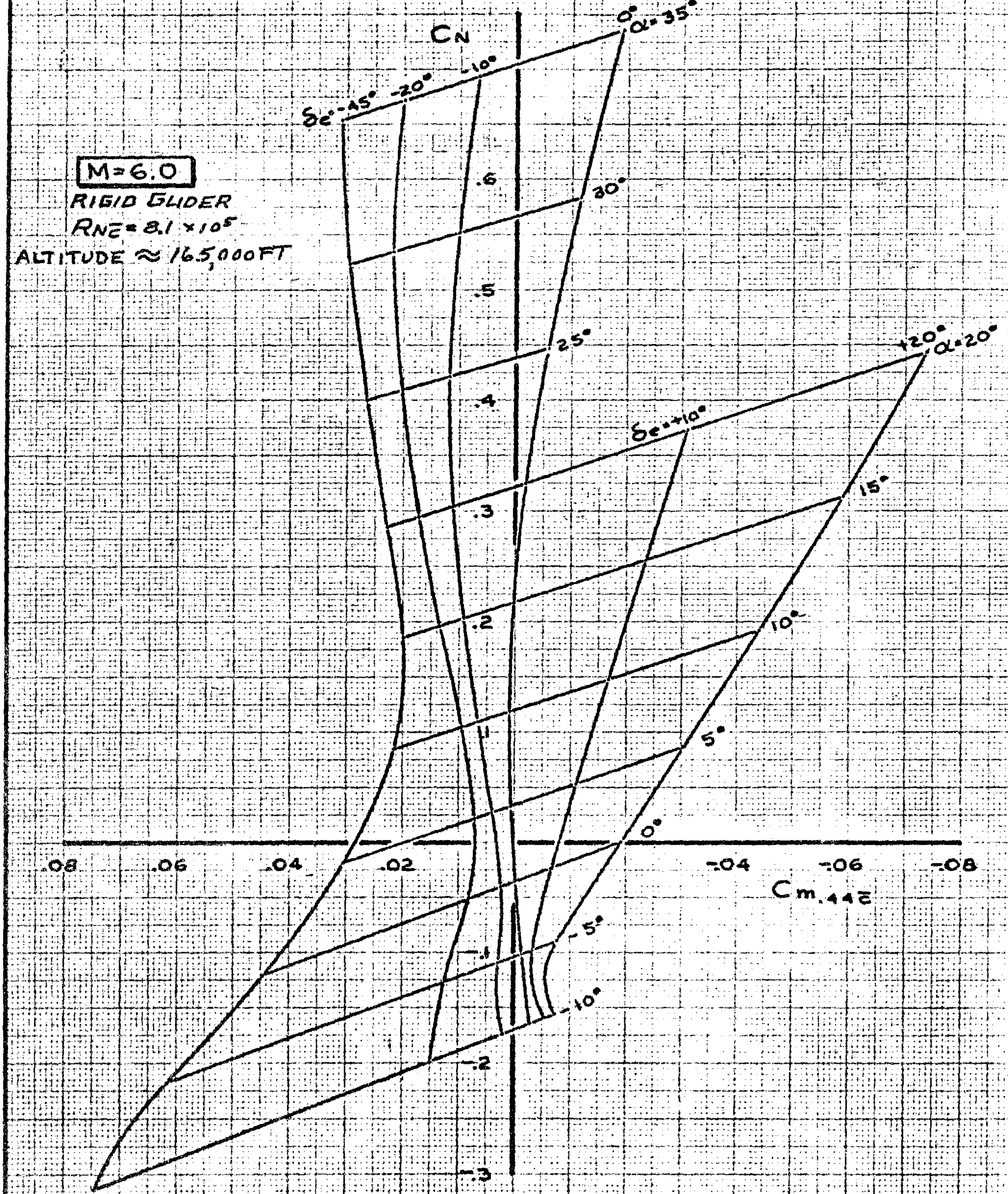

FIG. 6.18

			REVISED	DATE		
CALC	D. KATZ	11-13-61			HOT SHAPE LONGITUDINAL STABILITY M = 6.0	844-2050 D
CHECK			12-3-61			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.25
TRACE	N.H.	11-13-61				

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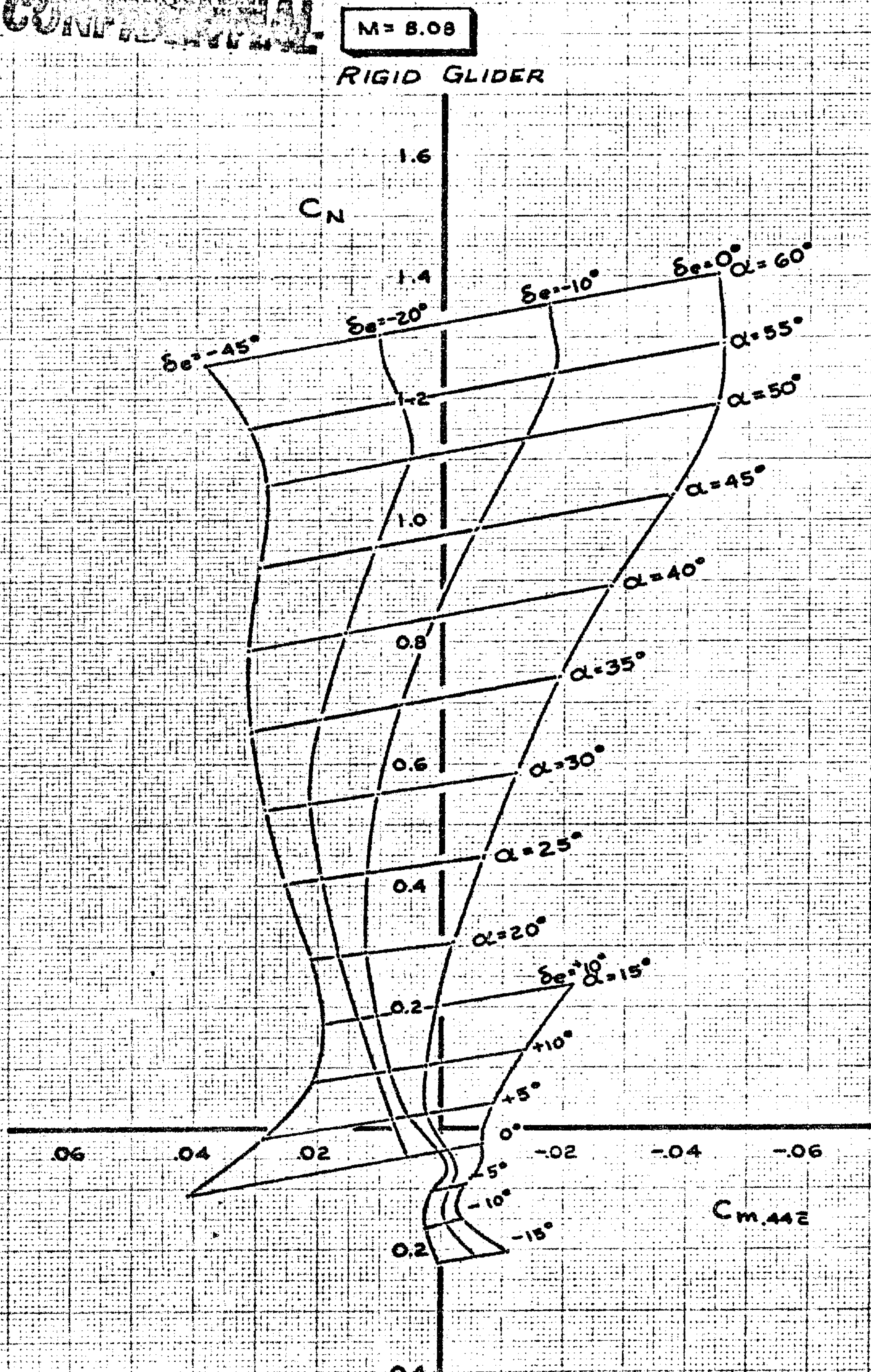

FIG. 6.19

CALC	J.L. FRANCIS	11-9-61	REVISED	DATE	HOT SHAPE LONGITUDINAL STABILITY M = 8.08	844-2050 D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.26
DRN	H.U.					

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M = 9.0

RIGID GLIDER

R_{N_Z} = 4.5 × 10⁵

ALTITUDE ≈ 195,000 FT

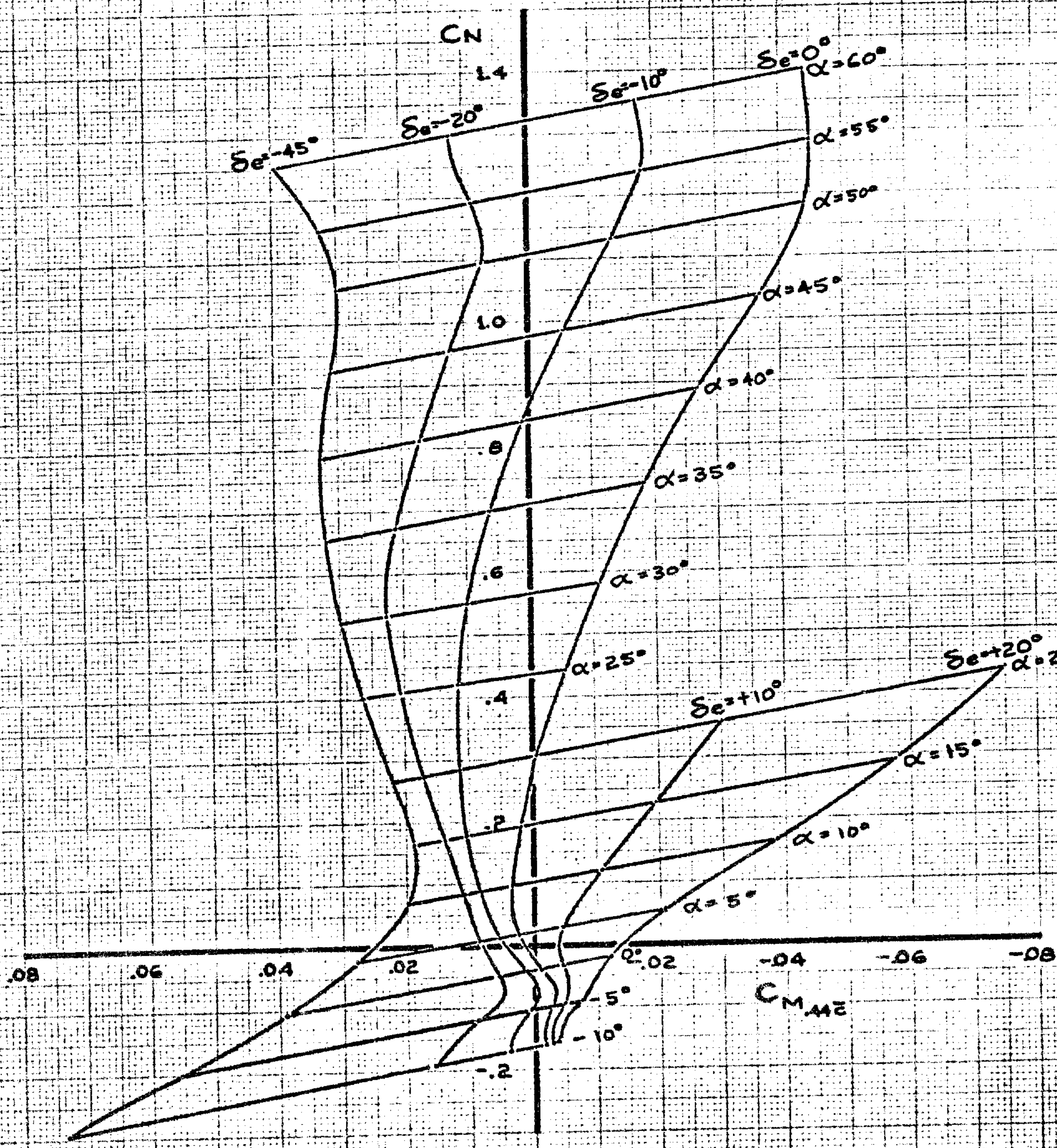

FIG. 6.20

CALC	J.L. FRANCIS	11/22/61	REVISED	DATE	HOT SHAPE LONGITUDINAL STABILITY M=9.0 LOW R_{N_Z}
CHECK					
APR					
APR					THE BOEING COMPANY
TRACE					

844-2050 D

D2-80065

PAGE 6.27

U3 4013 8000

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CONFIDENTIAL M = 9.0

RIGID GLIDER
$R_{N\bar{c}} = 8.1 \times 10^5$
ALTITUDE ≈ 180,000 FT

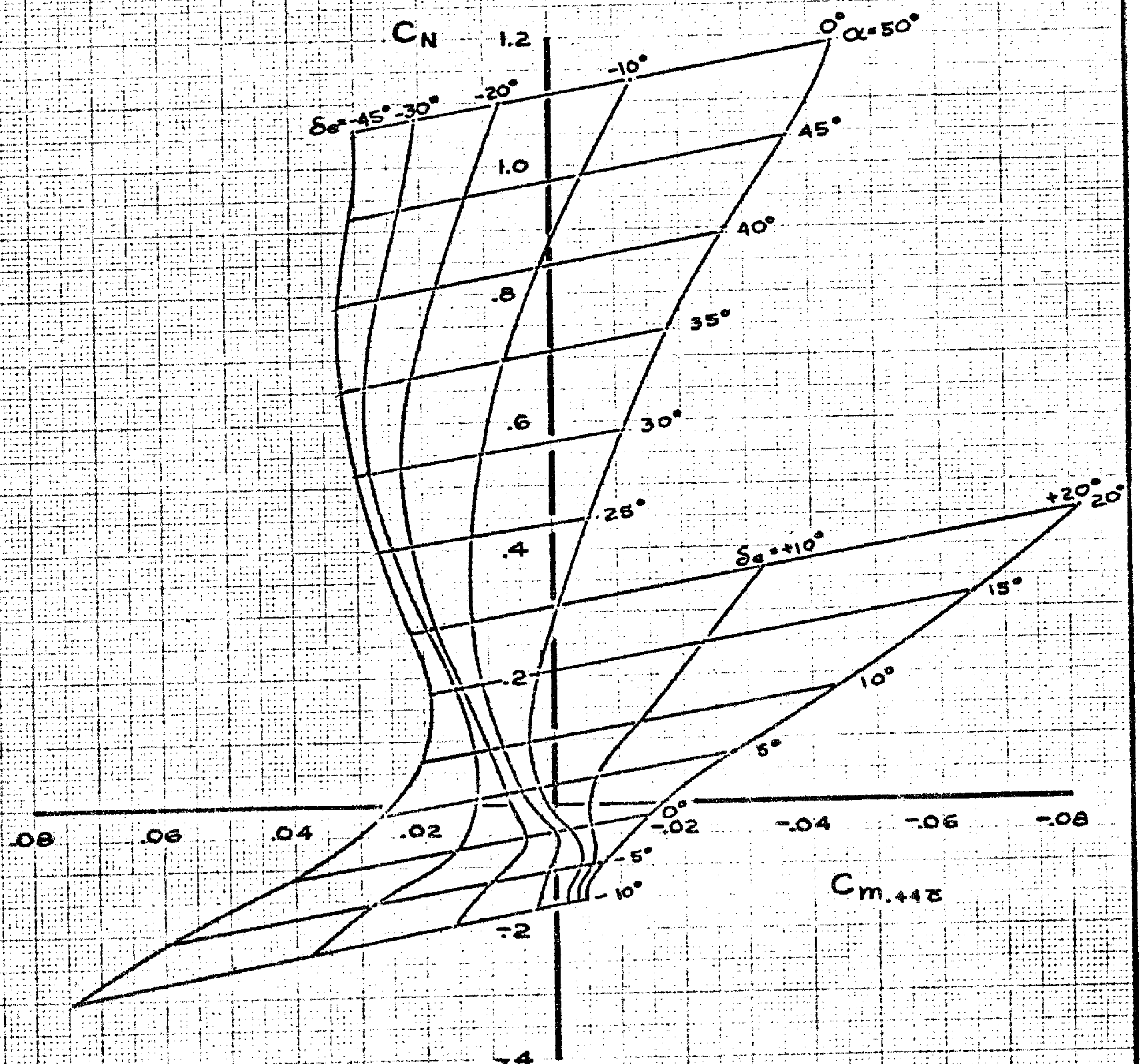

FIG. 6.21

CALC	J.L. FRANCIS	11/10/61	REVISED	DATE	HOT SHAPE LONGITUDINAL STABILITY M = 9.0	844 - 20500
CHECK			12-20-61			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.28
TRACE	N.U.	11-13-61				

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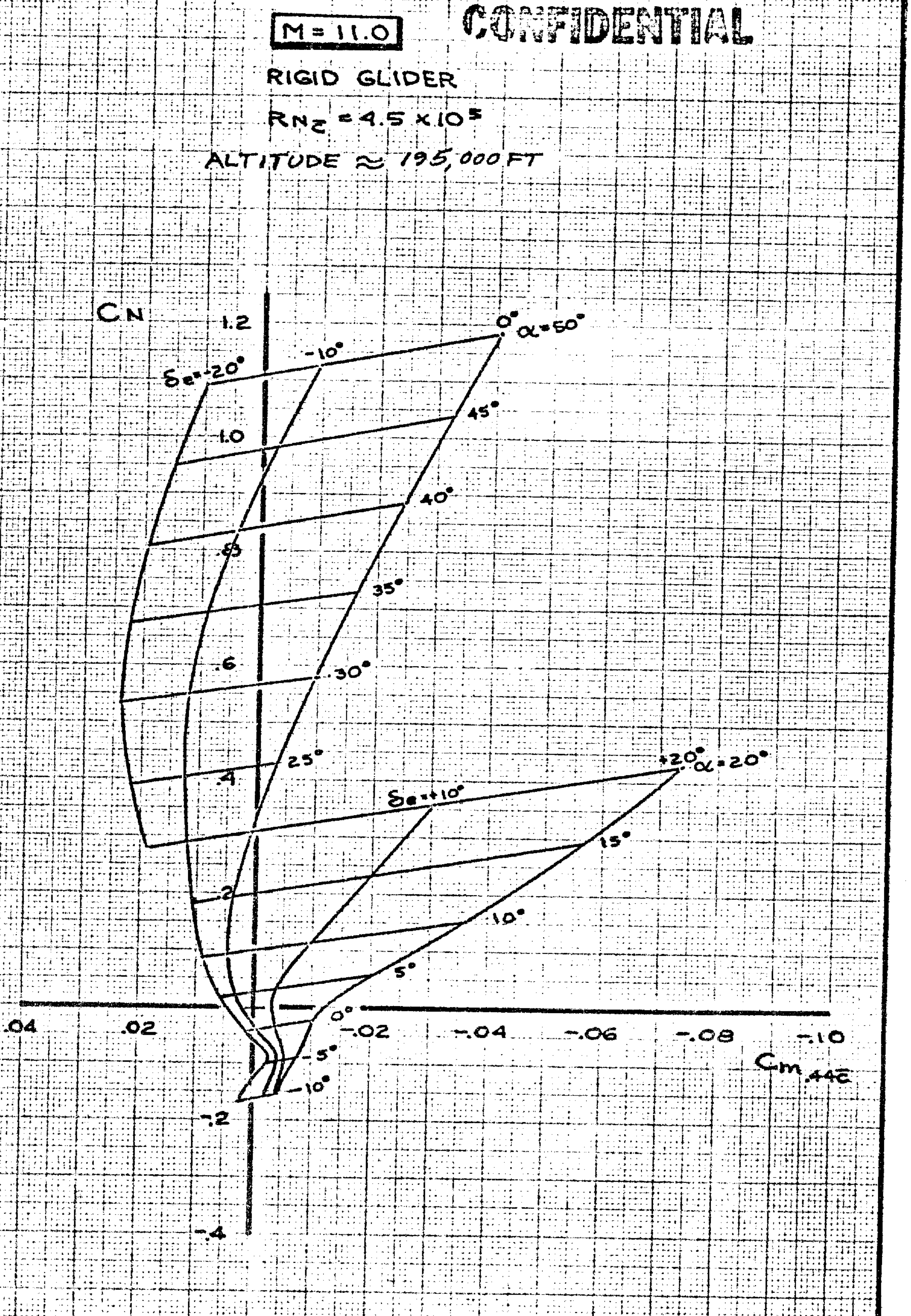

FIG. 6.22

CALC	D. KATZ	11-13-61	REVISED	DATE	HOT SHAPE LONGITUDINAL STABILITY M = 11.0	844-2050D
CHECK			12-2-61			
APR						D2-80065
APR					THE BOEING COMPANY	PAGE 6.29
TRACE	N.J.					

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M = 16.0

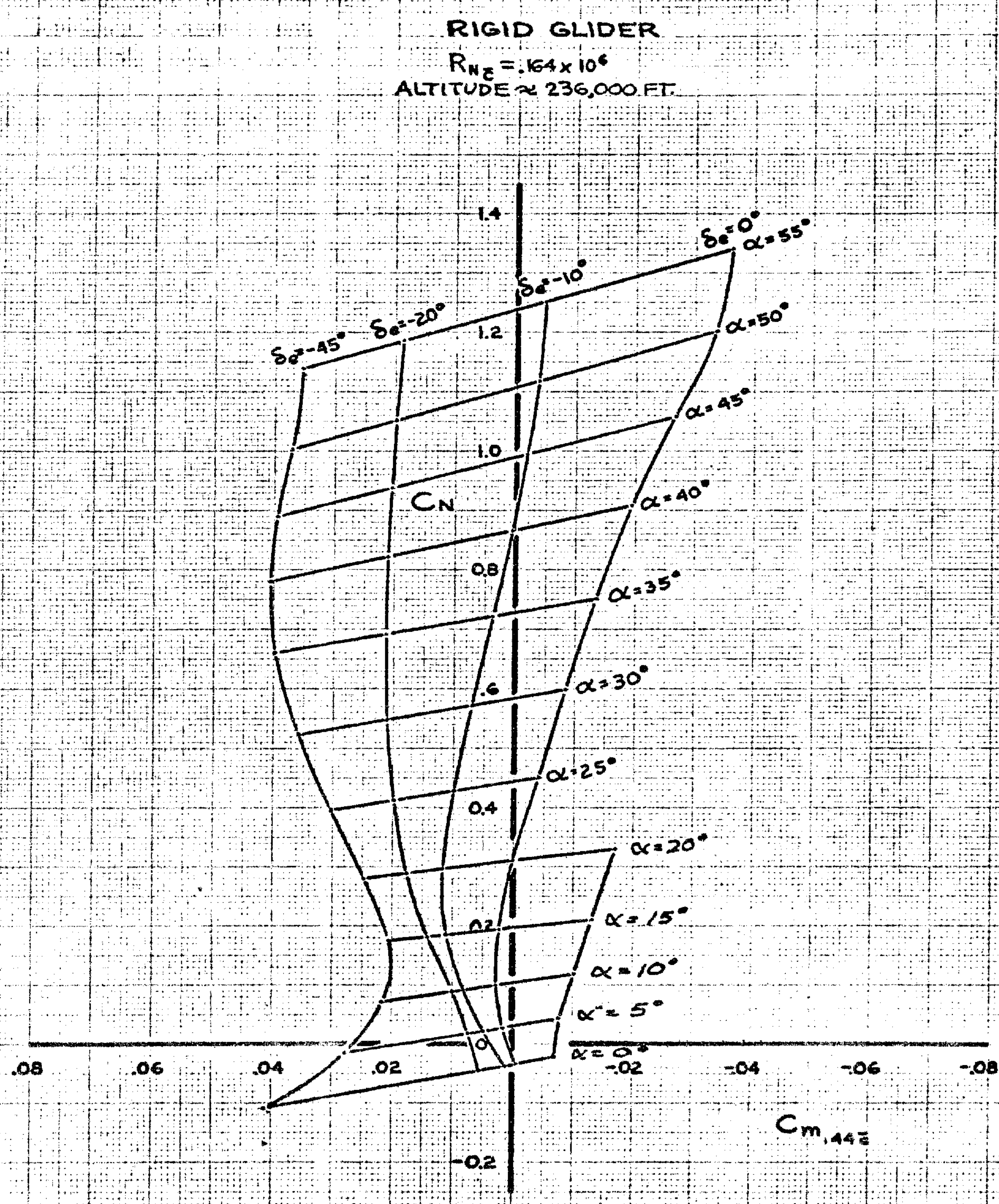

FIG. 6.23

CALC	E. PIPER	11-9-61	REVISED	DATE	HOT SHAPE LONGITUDINAL STABILITY M=16.0	844-20500
CHECK						
APR						D2-80065
APR					THE BOEING COMPANY	PAGE 6.30
TRACE						

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6.23

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M=22.0

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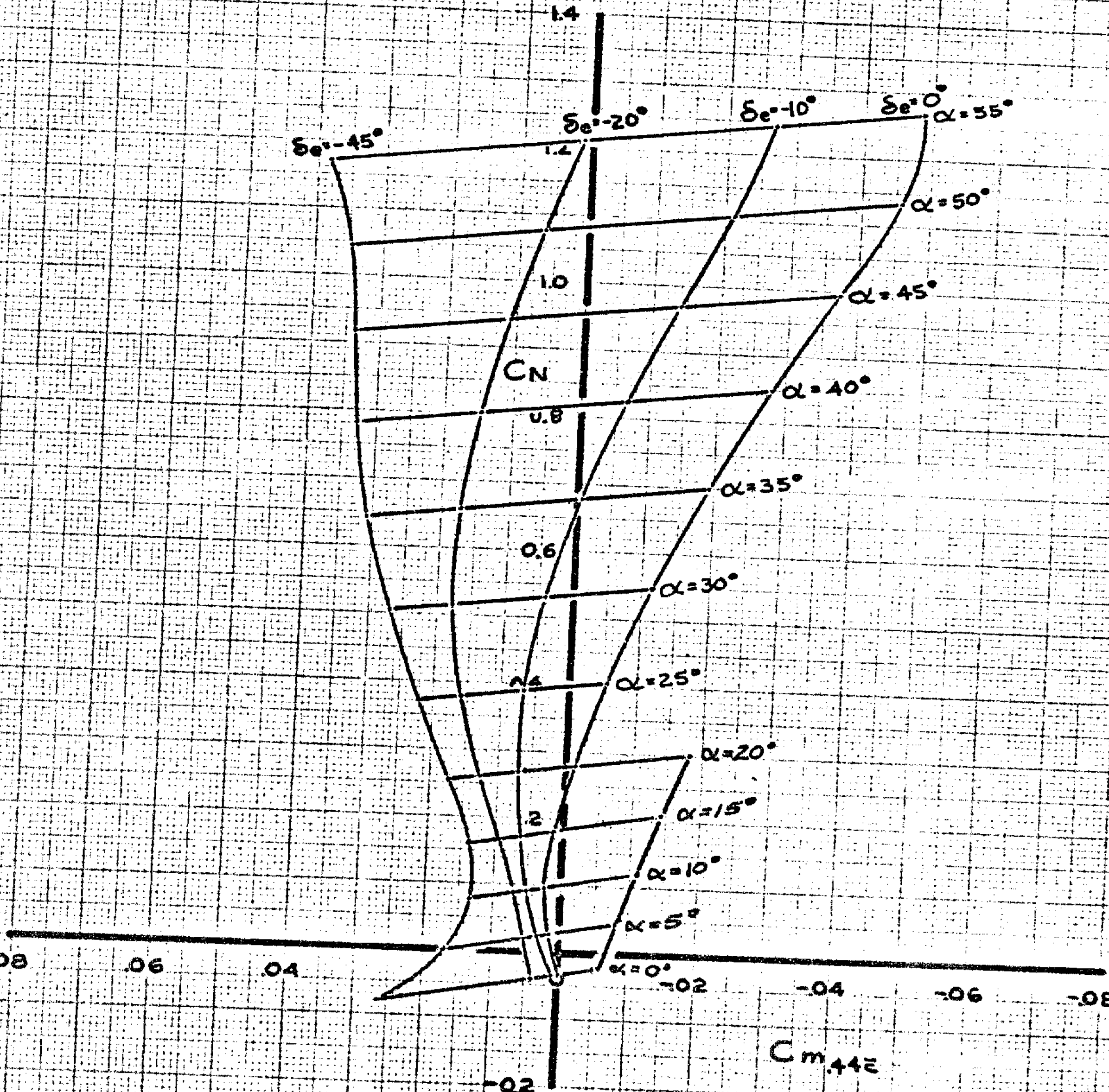
RIGID GLIDER
$R_{N_{\bar{c}}} = .066 \times 10^6$
ALTITUDE ≈ 263,000 FT.



CALC	E. PIPER	11-9-1	REVISED	DATE	HOT SHAPE LONGITUDINAL STABILITY M = 22.0	FIG. 6.24 844-2050D
CHECK						
APR						D2-80065
APR					THE BOEING COMPANY	PAGE 6.31

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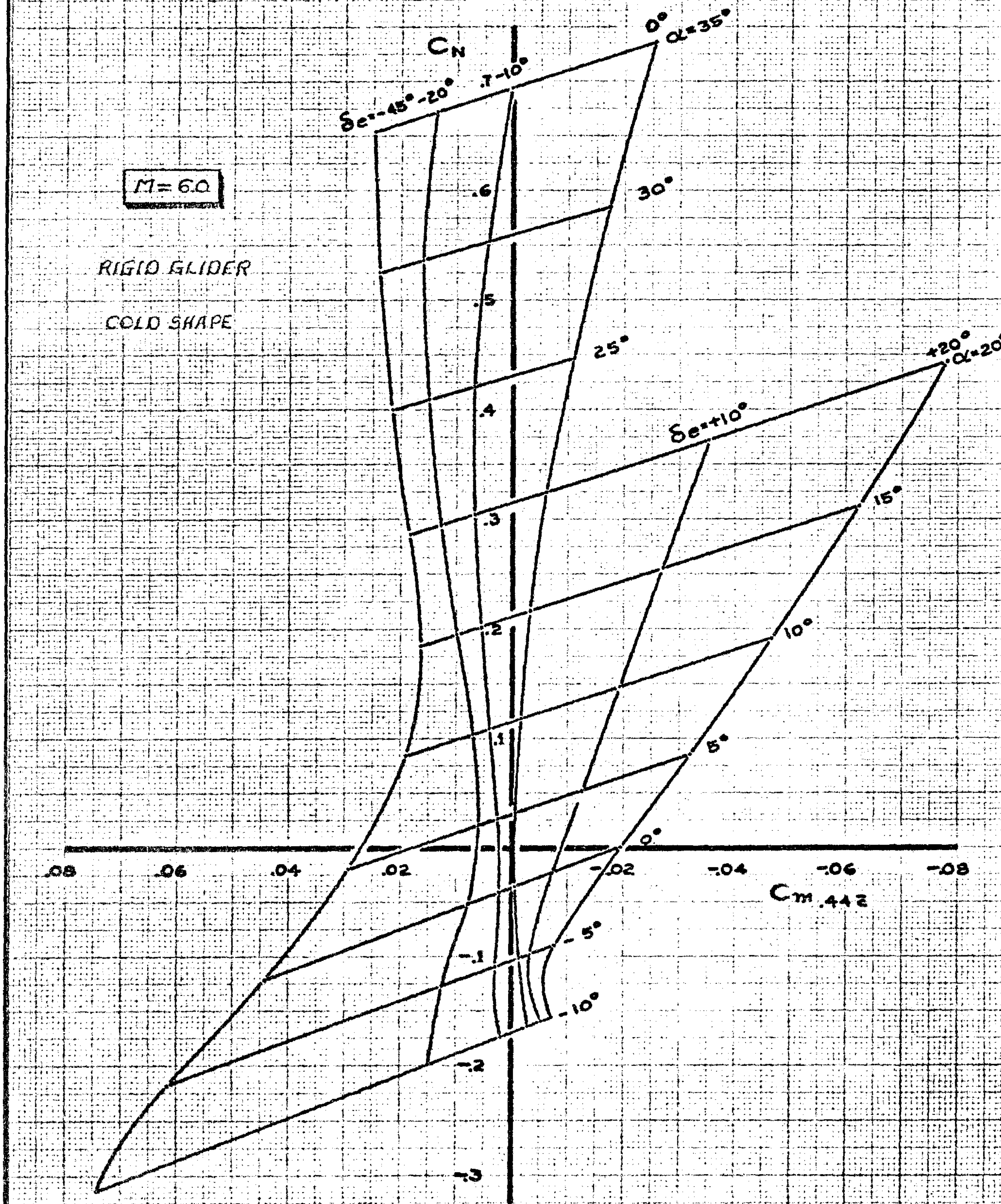

FIG. 6.25

CALC	G O K	11-13-61	REVISED	DATE	COLD SHAPE LONGITUDINAL STABILITY M = 6.0	844-2050 D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.32
APR						
DRN		12-13-61				

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M= 8.08

RIGID GLIDER

COLD SHAPE

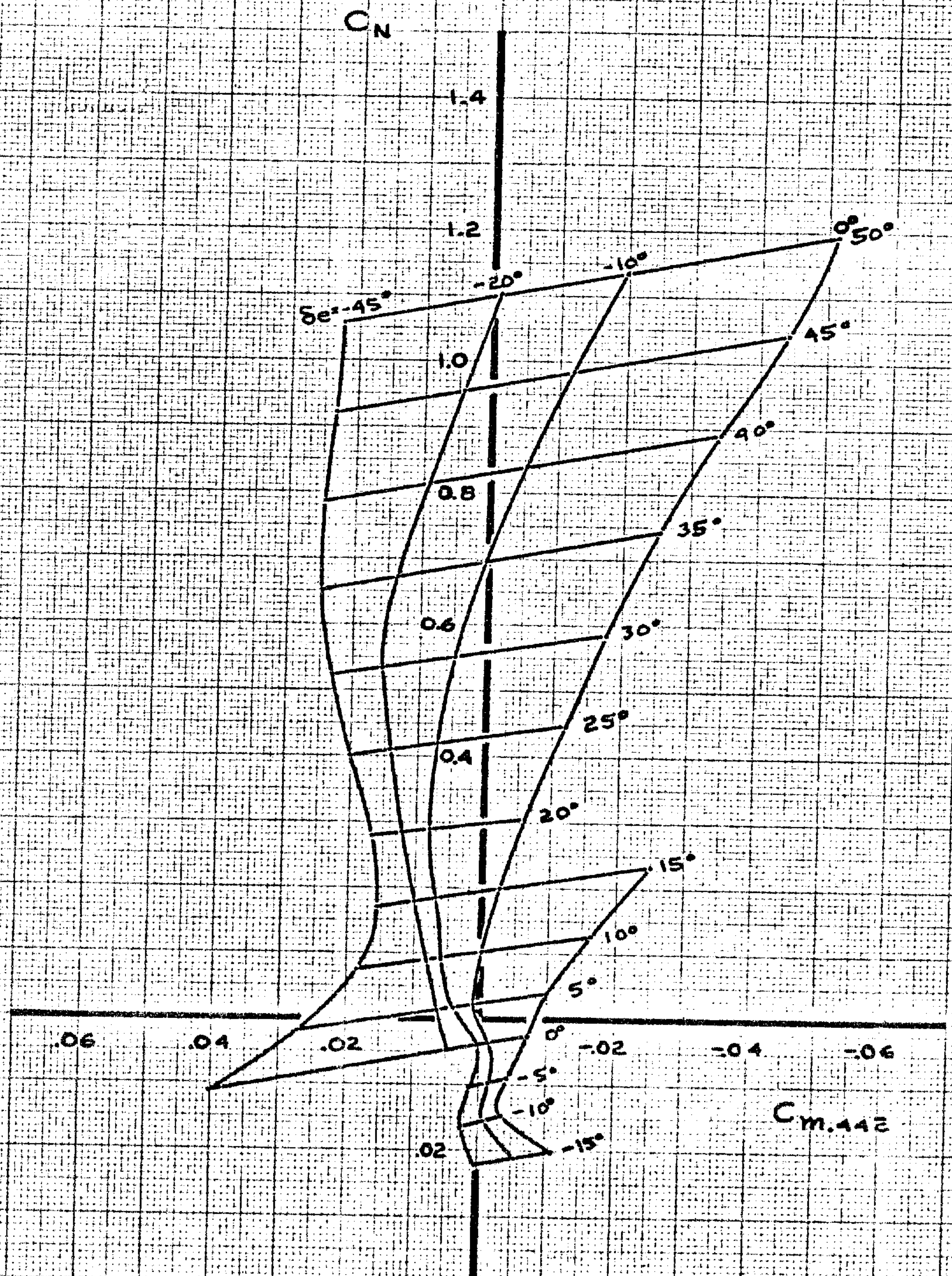

FIG. 6.26

CALC	GDK	12-11-61	REVISED	DATE	COLD SHAPE LONGITUDINAL STABILITY M = 8.08	844-2060.0
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.33
APR						

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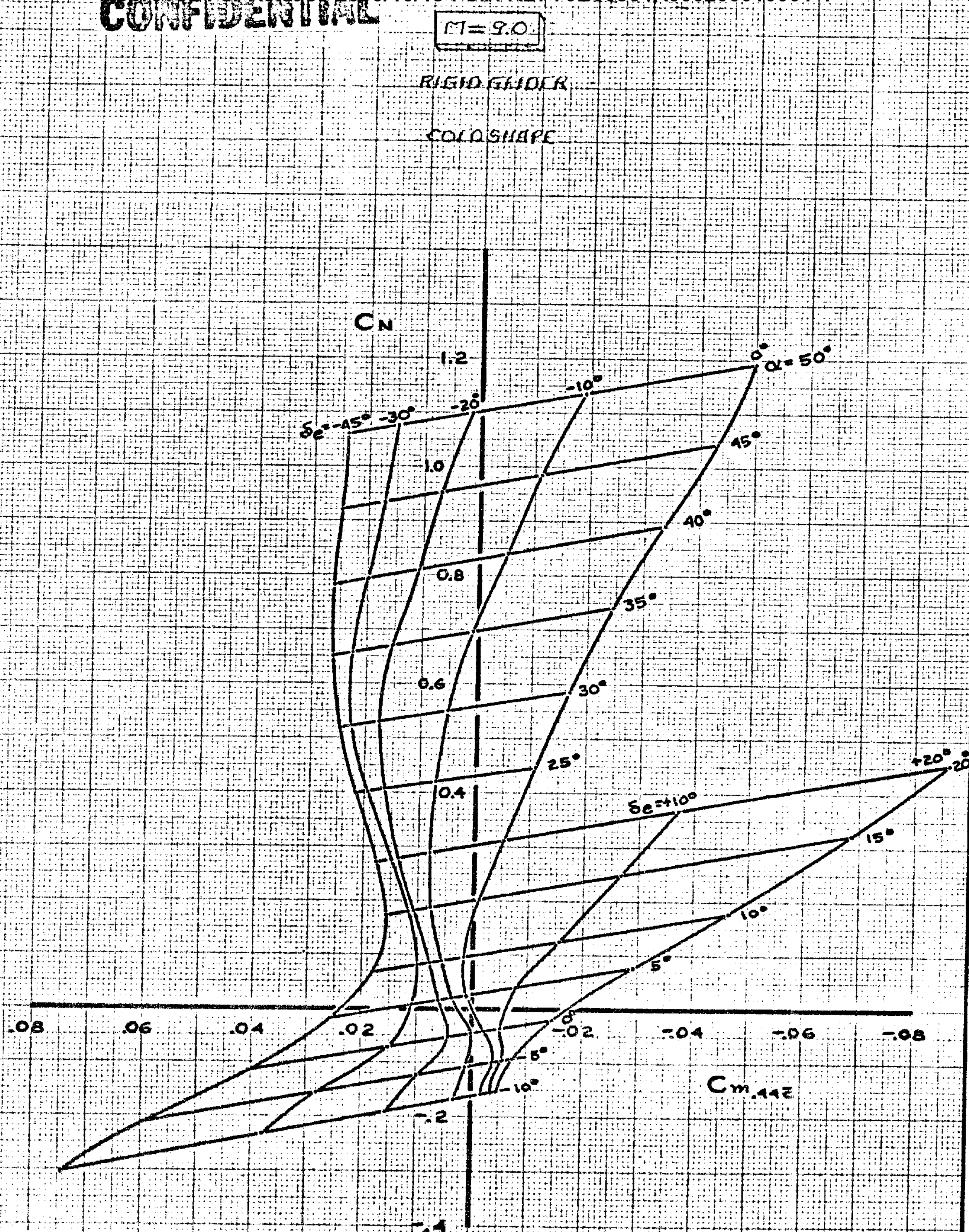

FIG. 6.27

CALC	G D K	12-11-61	REVISED	DATE	COLD SHAPE LONGITUDINAL STABILITY M=9.0	844-20500
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.34
APR						

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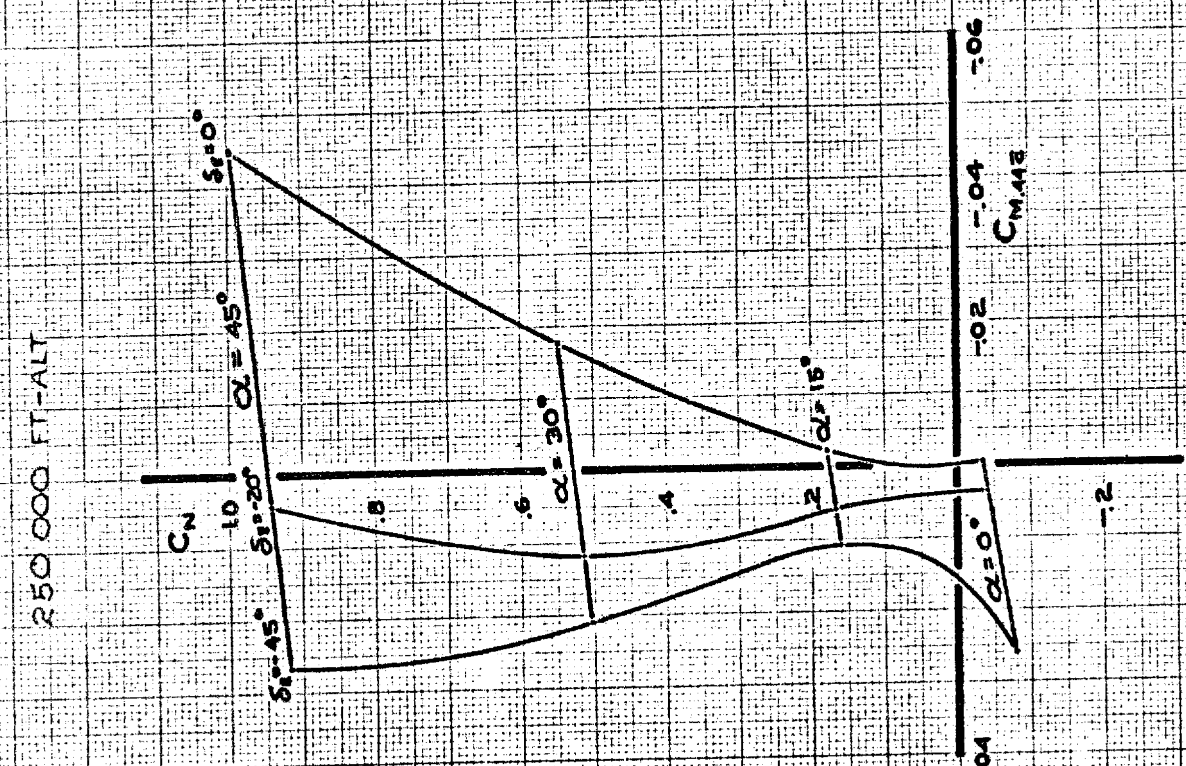

FIG. 6. 28

CALC	J.L. FRANCIS	12/14/61	REVISED	DATE	COLD SHAPE LONGITUDINAL STABILITY 250.000 FT ALT
CHECK			12-...		
APR					
APR					THE BOEING COMPANY

844-2050 D

D2-80065

PAGE 6.35

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US 4013 6000

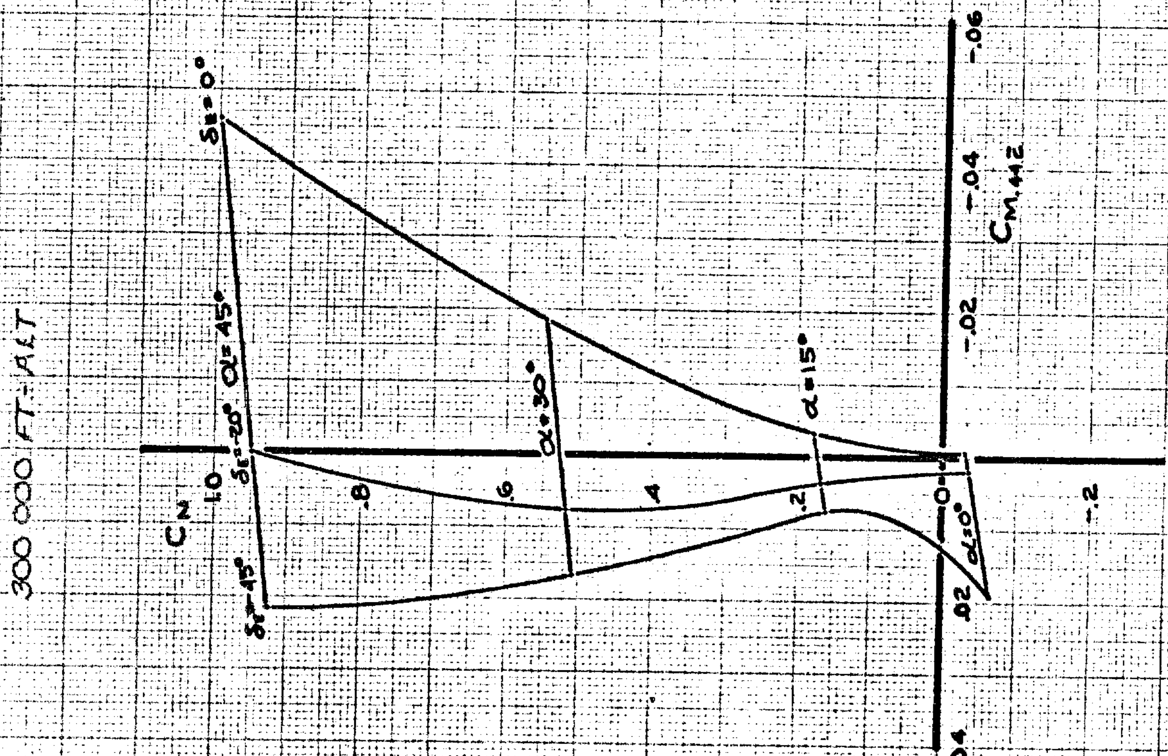

FIG. 6.29

CALC	J.L.F./G.D.K.	12/14/61	REVISED	DATE	COLD SHAPE LONGITUDINAL STABILITY 300 000 FT-ALT	844-2050 D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.36
APR						

US 4013 8000

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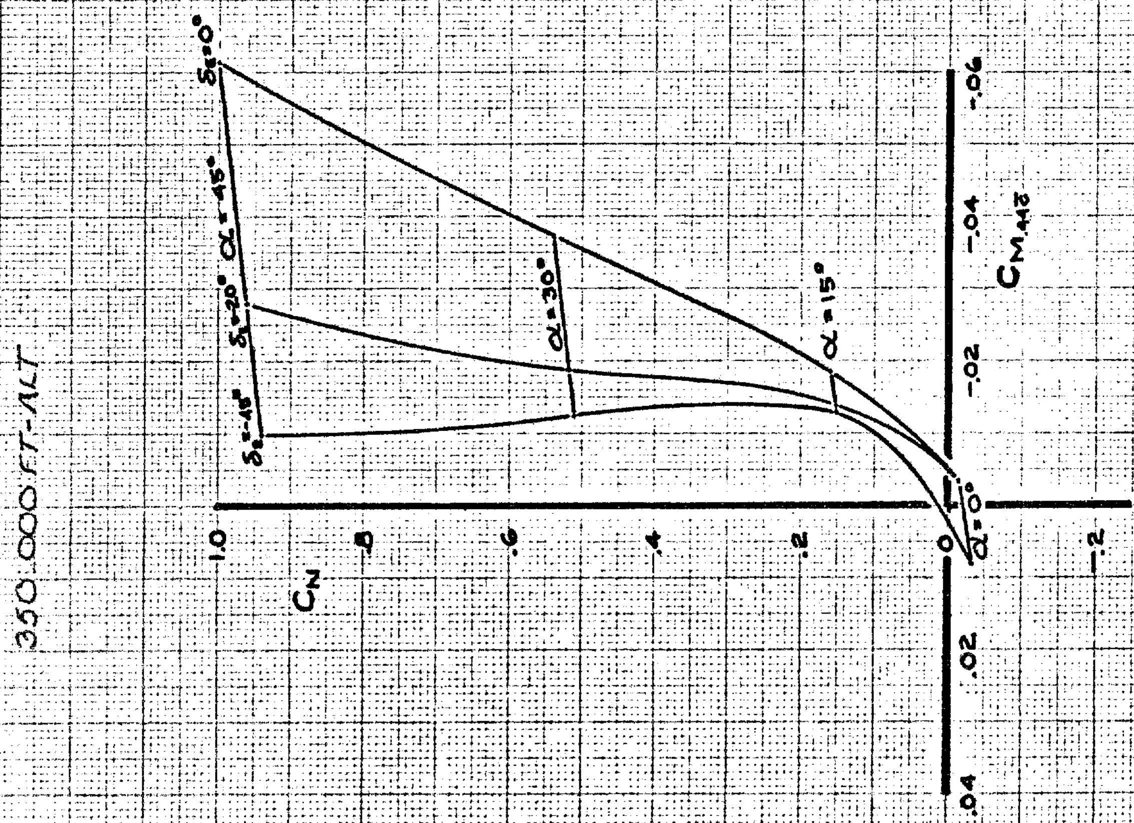

FIG. 6.30

CALC	J.L.F./G.D.K.	12/14/61	REVISED	DATE	COLD SHAPE LONGITUDINAL STABILITY 350 000 FT-ALT	844-2050 D
CHECK			2-20-?			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.37

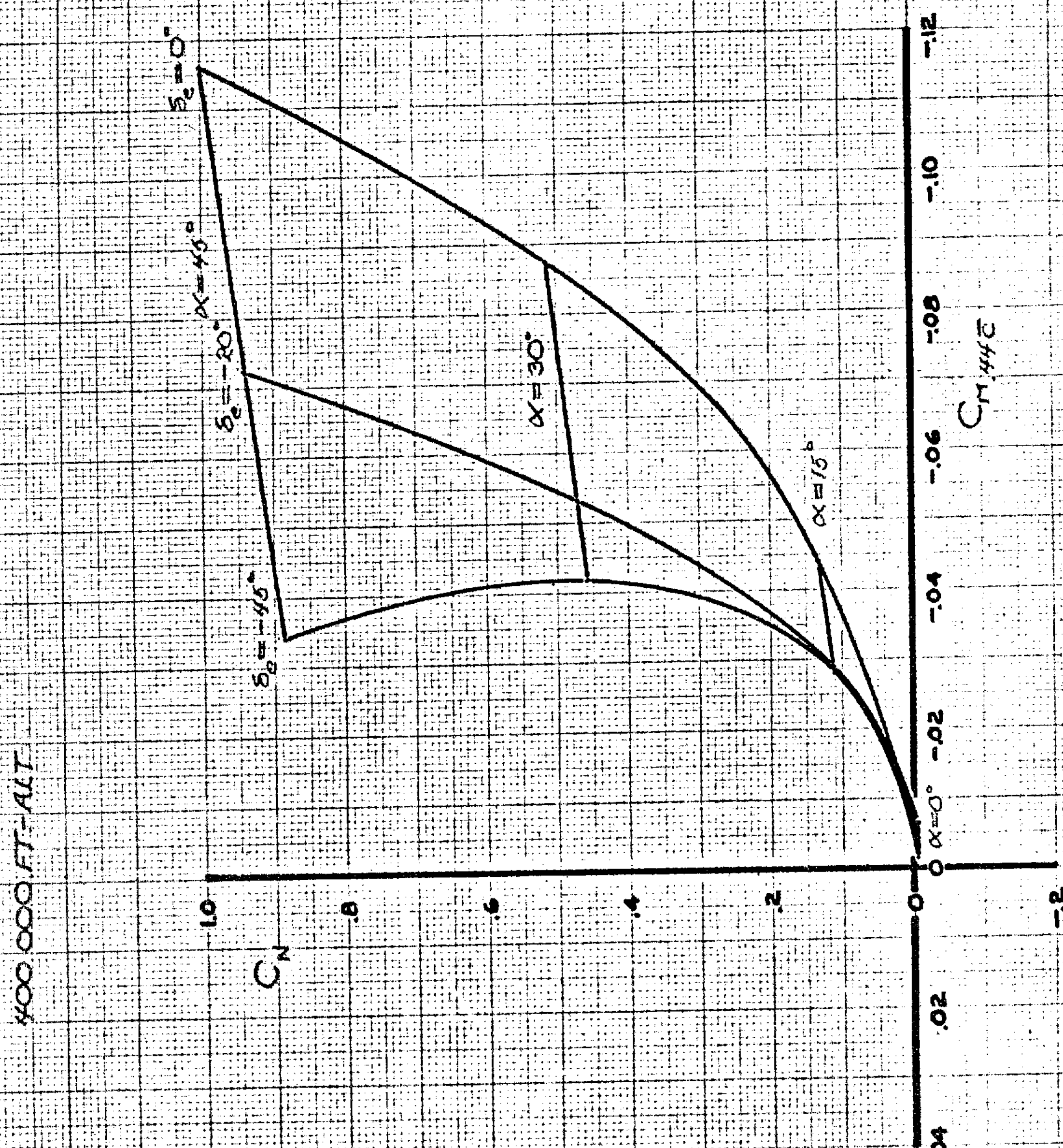

FIG. 6.31

CALC	J.L. FRANCIS	12/14/61	REVISED	DATE	COLD SHAPE LONGITUDINAL STABILITY 400 000 FT-ALT
CHECK					
APR					THE BOEING COMPANY
APR					

844-2050 D.

D2-80065

PAGE 6.38

U3 4013 8000

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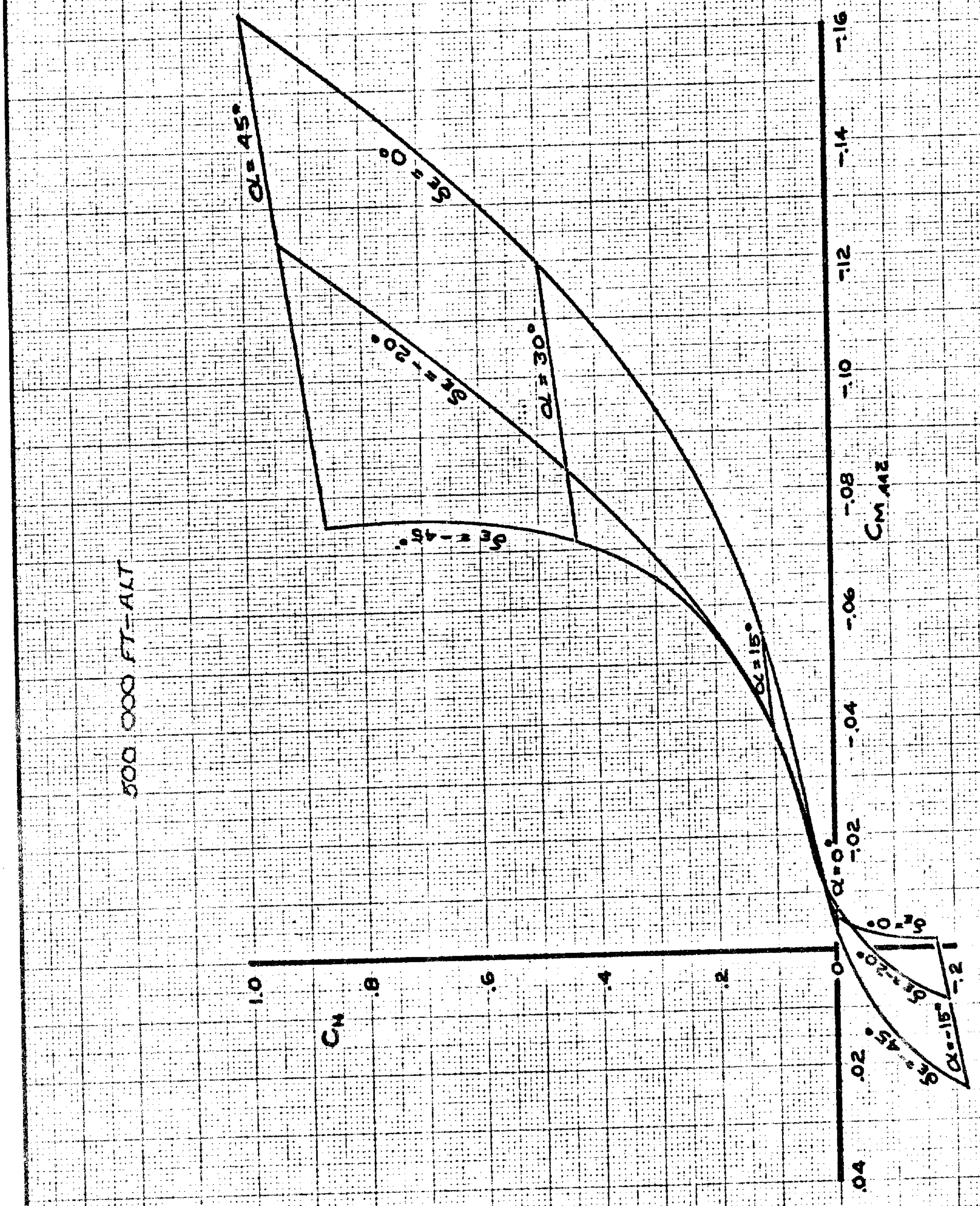

FIG. 6.32

CALC	J.L.Francis	10/3/61	REVISED	DATE
CHECK				
APR				
APR				

COLD SHAPE
LONGITUDINAL STABILITY
500 000 FT-ALT

THE BOEING COMPANY

244-2050 D

D2-80065

PAGE 6.39

M = 6.0

RIGID GLIDER
HOT SHAPE

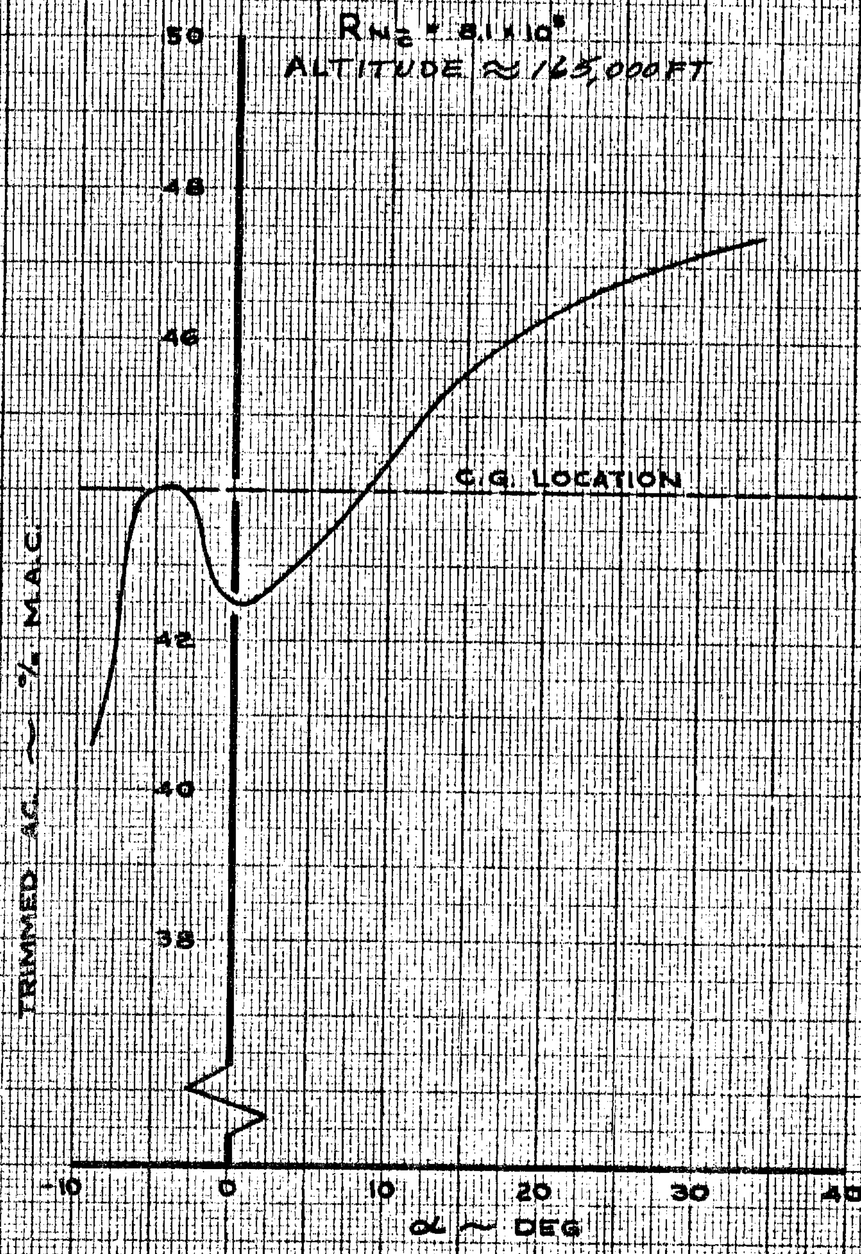

FIG. 6.33

CALC	J.J. FRANCIS	11-10-61	REVISED	DATE	TRIMMED LONGITUDINAL AERODYNAMIC CENTER M = 6.0	844-2050 D
CHECK			12-20-1			
APR						D2-80066
APR					THE BOEING COMPANY	PAGE
TRACE	N.U.	11-10-61				6.40

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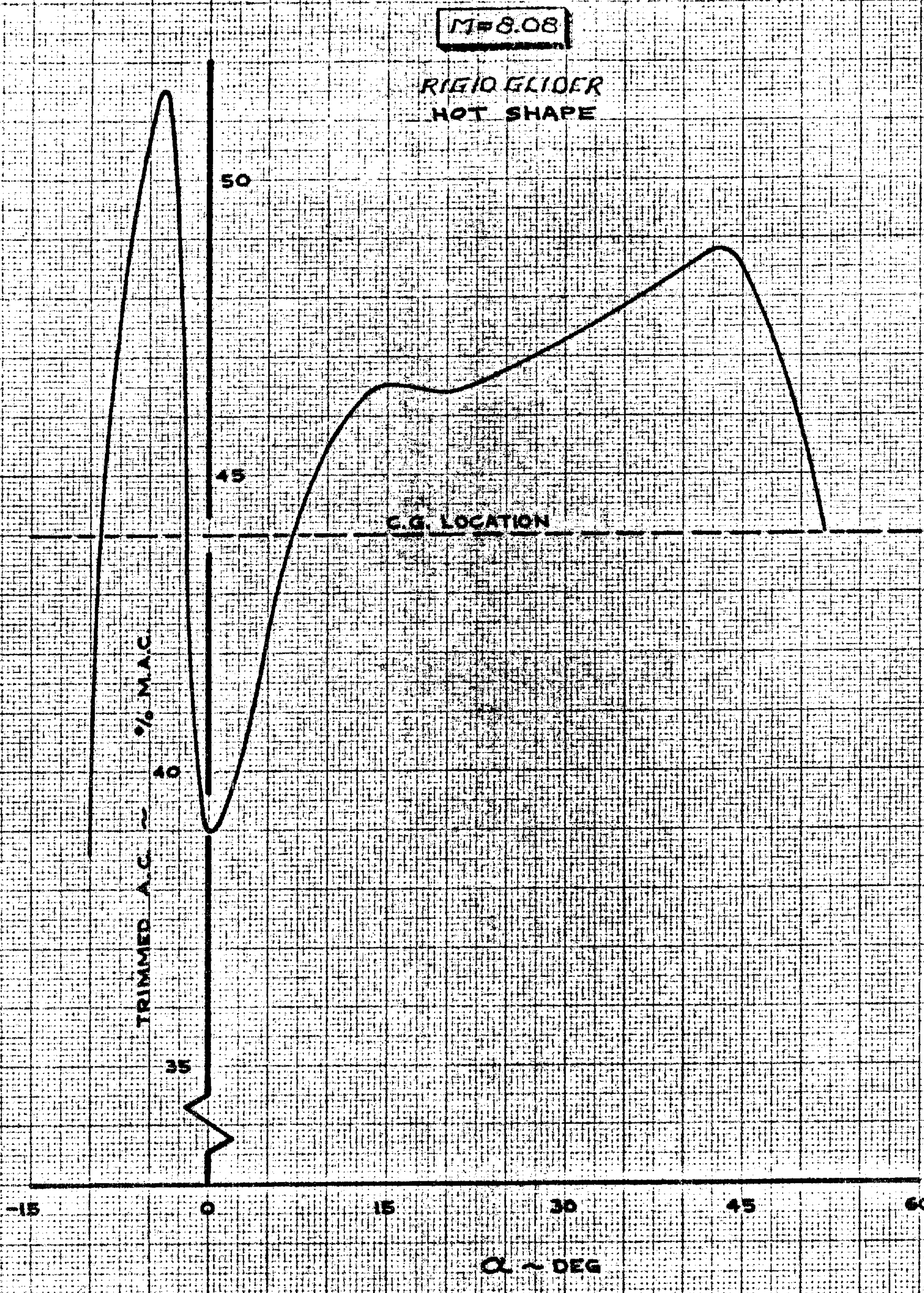

FIG. C.34

			REVISED	DATE		
CALC	J.L. FRANCIS				TRIMMED LONGITUDINAL AERODYNAMIC CENTER M=8.08	844-2050 D
CHECK			12-20-1			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.41
DRN.	N.U.	11-9-61				

U3 4013 8000

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68587

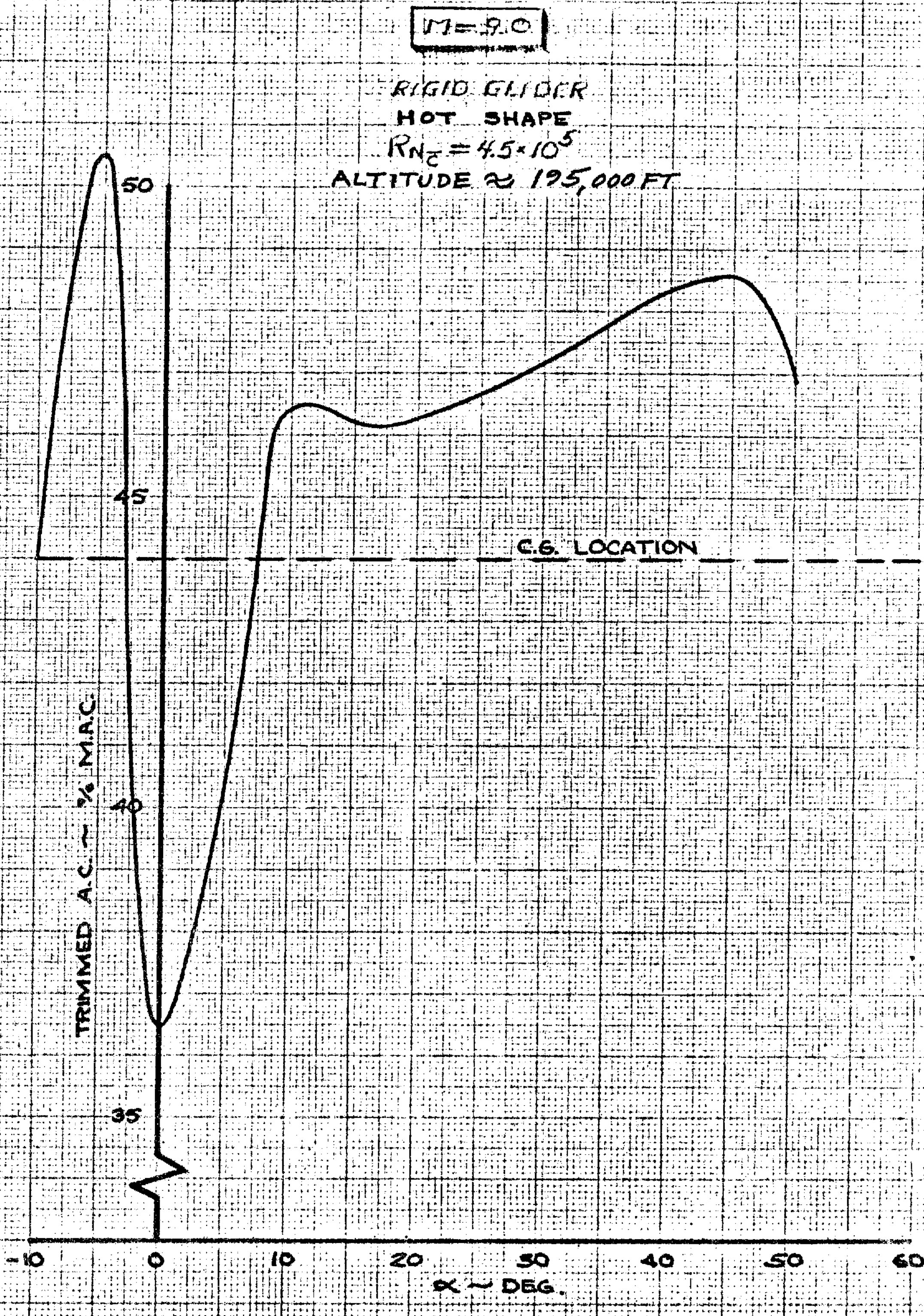

FIG. 6.35

CALC	J.L. FRANCIS	12/13/61	REVISED	DATE	TRIMMED LONGITUDINAL AERODYNAMIC CENTER M = 9.0 LOW $R_{N_{\bar{c}}}$
CHECK					
APR					
APR					THE BOEING COMPANY

844-2050 D

D2-80065

PAGE 6.42

US 4013 8000

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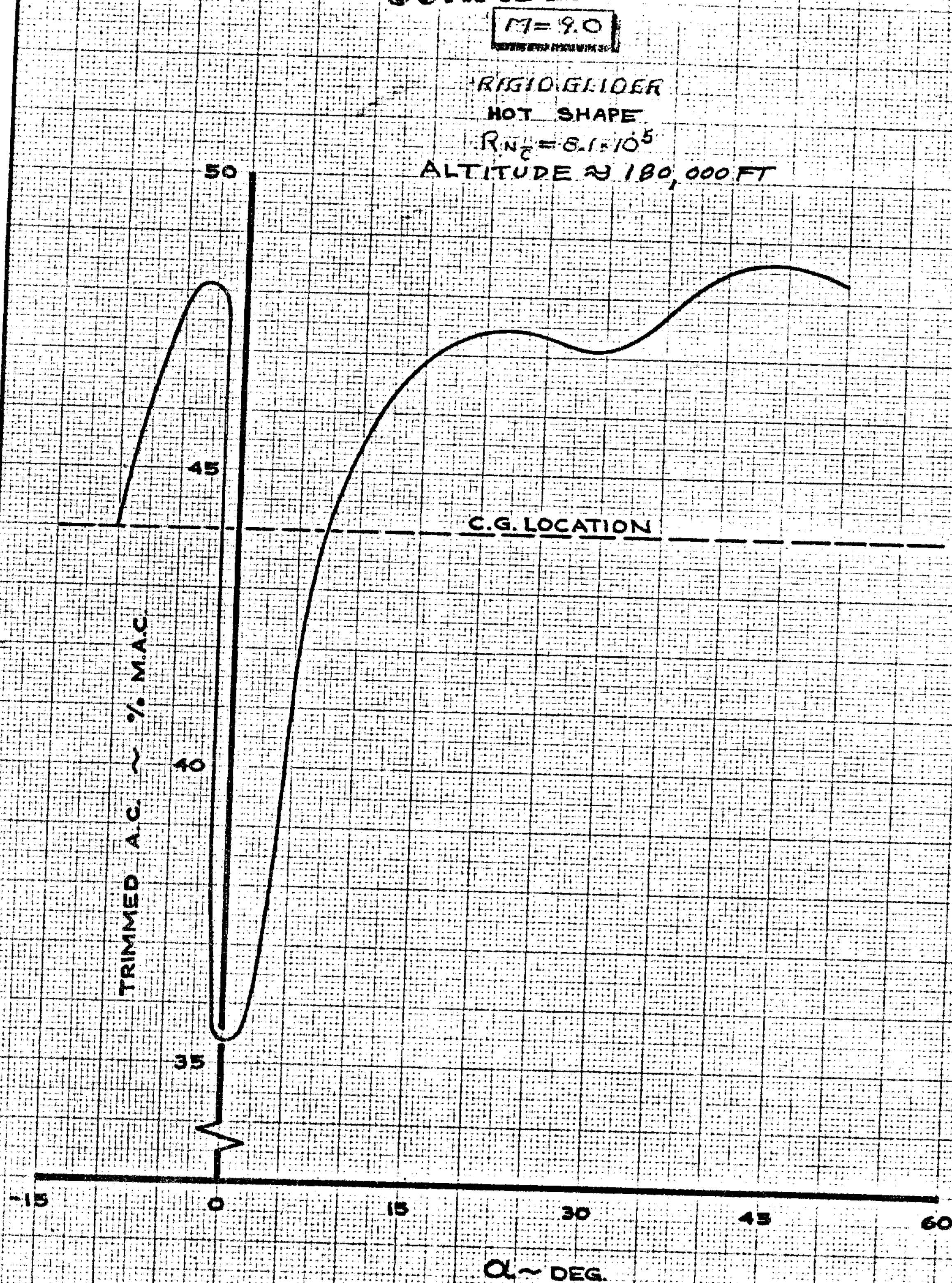

CALC	Emp	11/14/61	REVISED	DATE
CHECK			11-20-61	
APR				
APR				
TRACE	N.U.	11-17-61		

FIG. 6.36

M = 9.0

TRIMMED LONGITUDINAL AERODYNAMIC CENTER

844-2050D

D2-80065

THE BOEING COMPANY

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US 4013 8000

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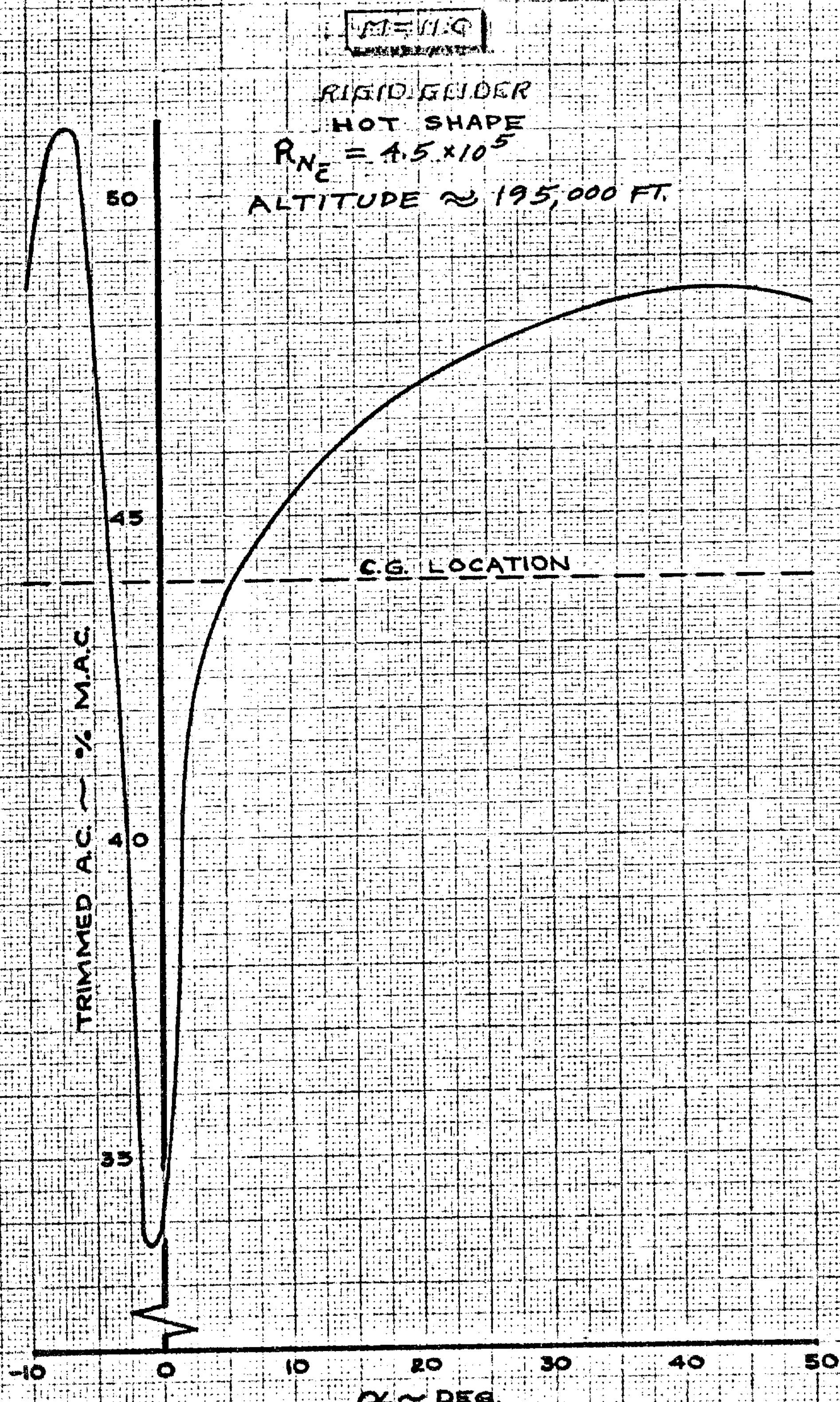

FIG. 6.37

CALC	J.L.FRANCIS	11/14/61	REVISED	DATE	TRIMMED LONGITUDINAL AERODYNAMIC CENTER M=11.0	844-20500
CHECK			12-20-1			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.44

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ALBANENE 196L TRACING PAPER 60629

CONFIDENTIAL

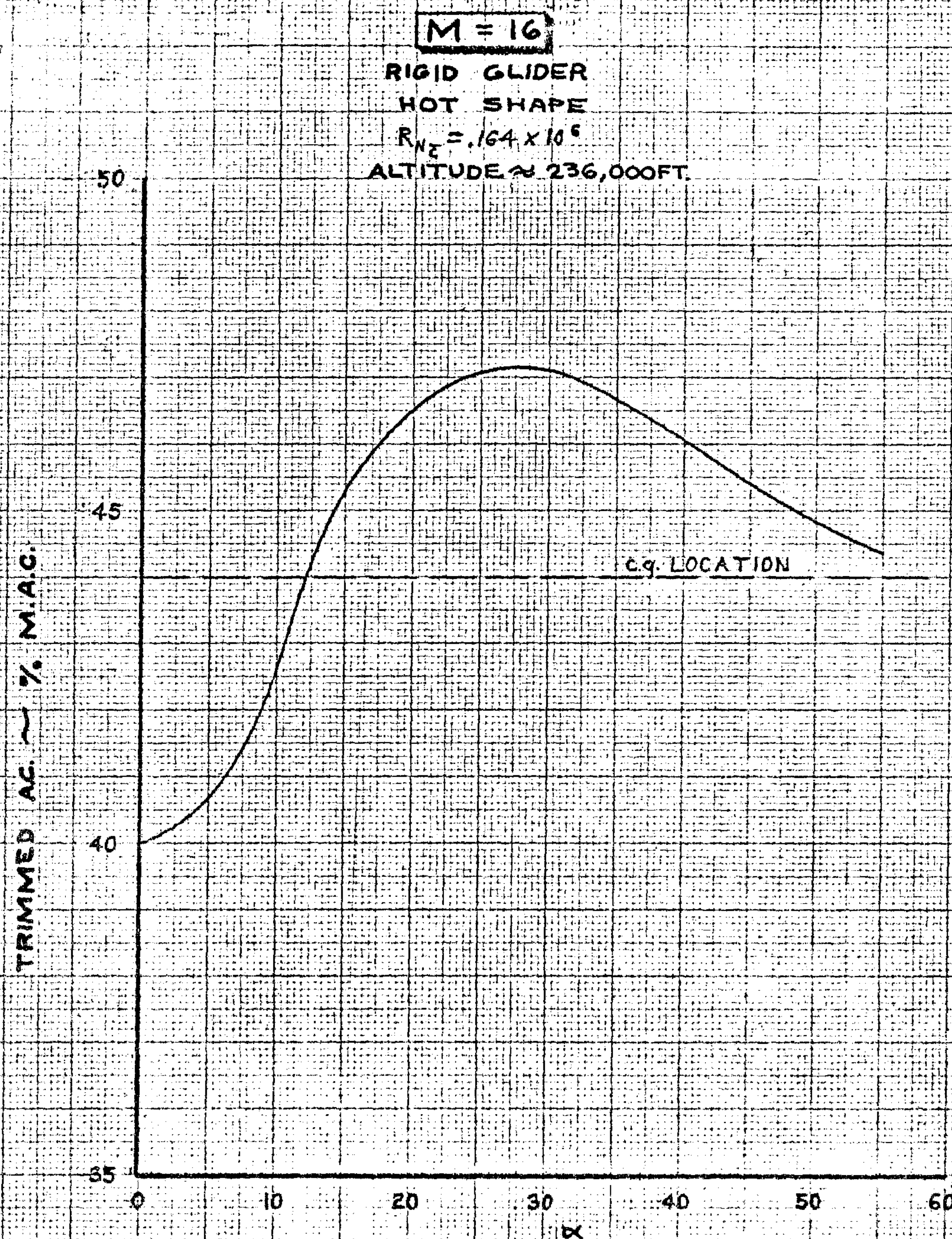

FIG. 6.38

CALC	E.M.P.		REVISED	DATE	TRIMMED LONGITUDINAL AERODYNAMIC CENTER M = 16	844-2050 D
CHECK			12-...			D2-80065
APR					THE BOEING COMPANY	PAGE 6.45
APR						

6.38

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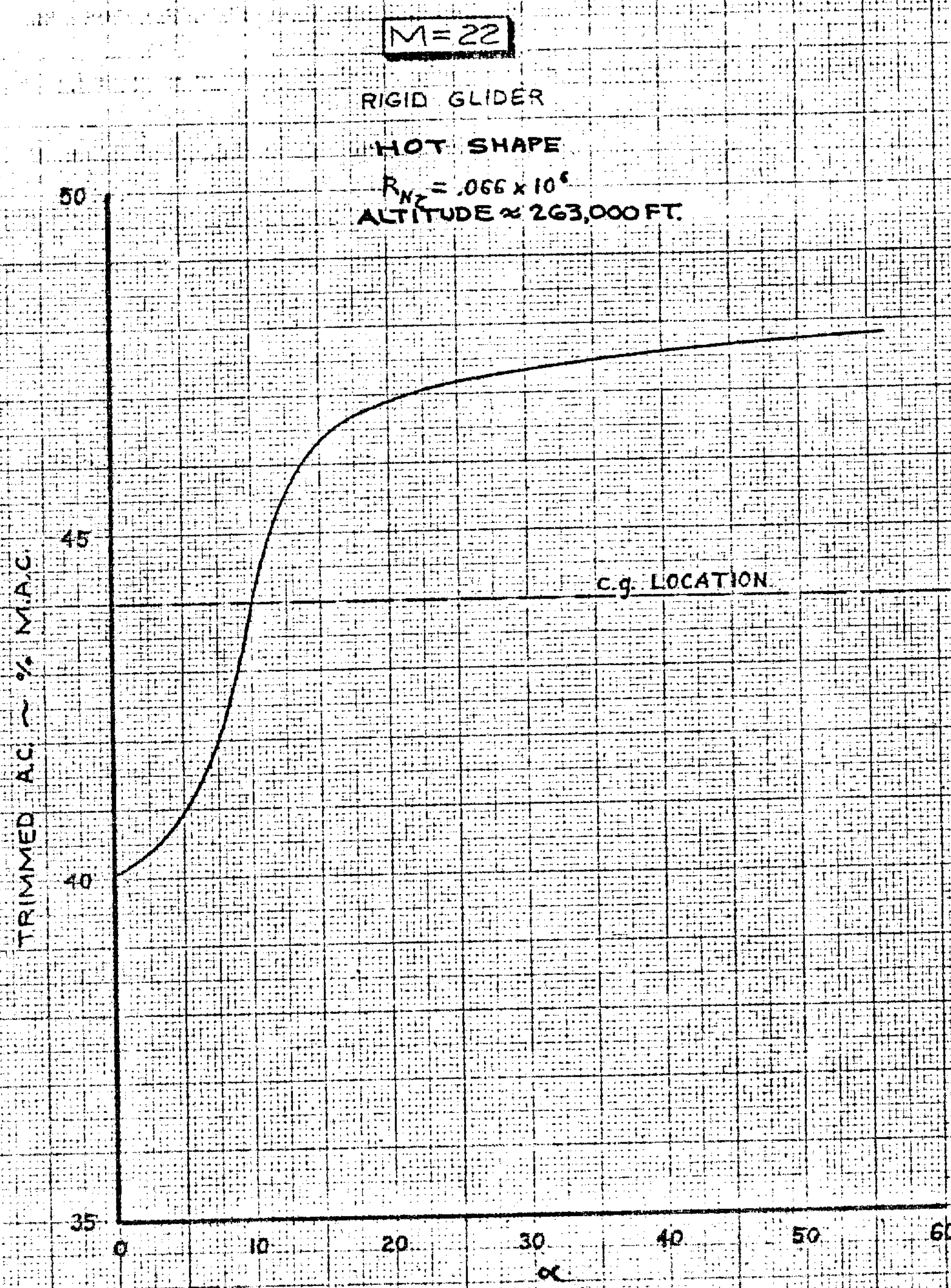

FIG. 6.39

CALC	E.M.P.	REVISED	DATE	TRIMMED LONGITUDINAL AERODYNAMIC CENTER M =22	644-2050 D
CHECK		12-30-?			D2-80065
APR				THE BOEING COMPANY	PAGE 6.46
APR					

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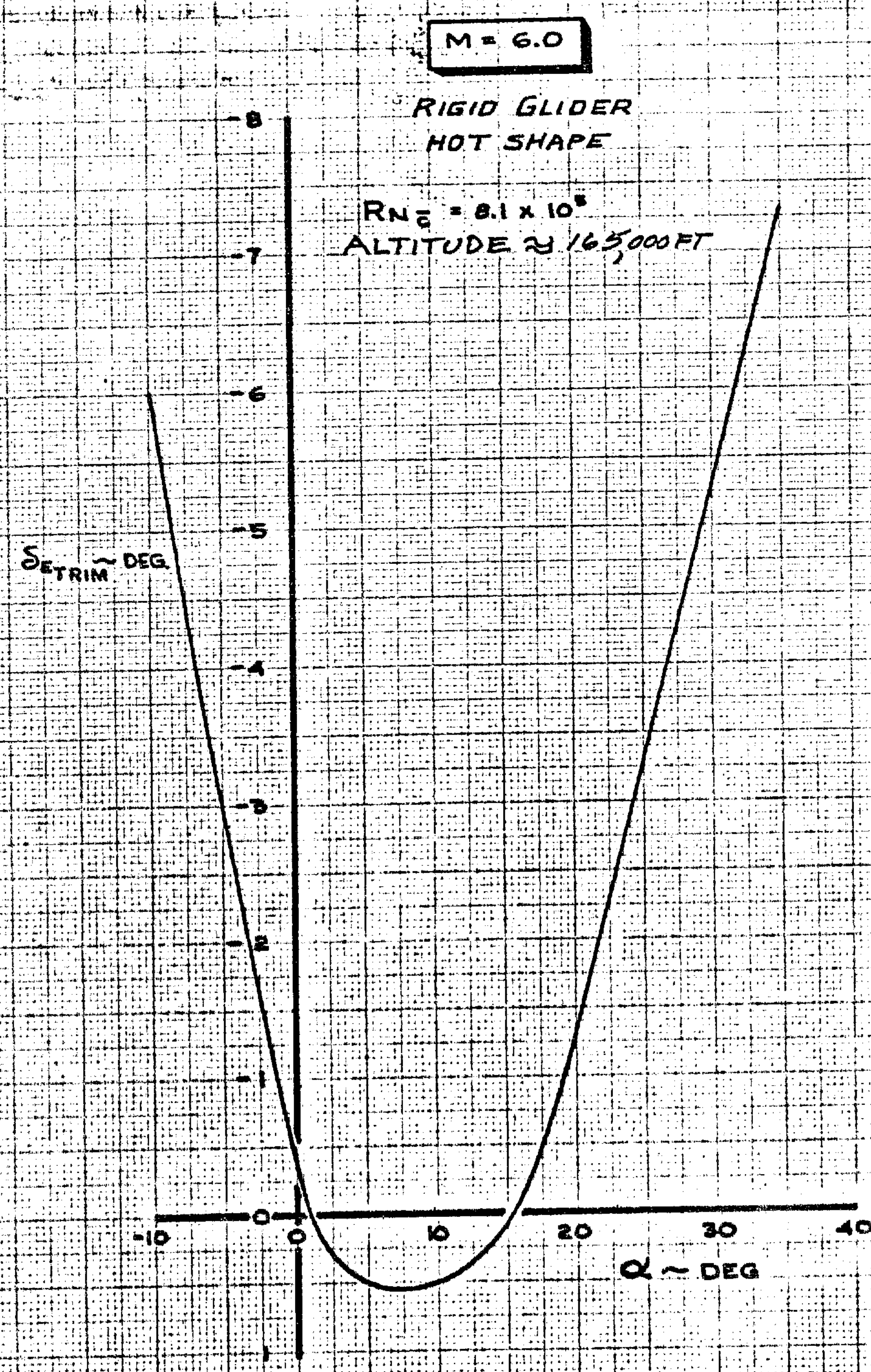

FIG. 6.40

CALC	J.L.FRANCIS	11-10-61	REVISED	DATE	ELEVON REQUIRED TO TRIM M= 6.0	844-2050 D
CHECK			12-20-1			D2-80065
APR					THE BOEING COMPANY	PAGE 6.47
APR						
TRACE	N.D.	11-16-61				

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U3 4013 8000

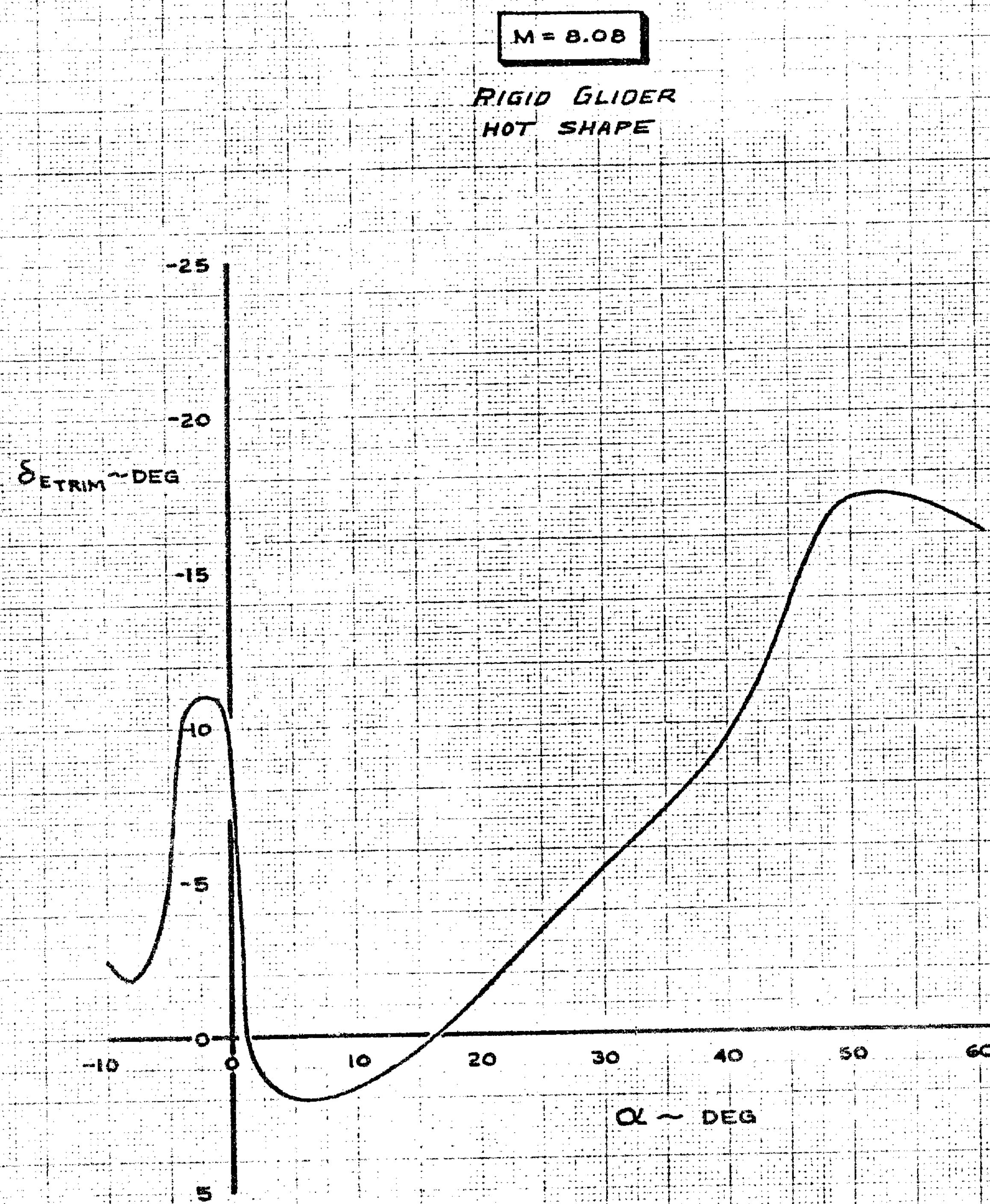

FIG. 6.41

CALC	J.L.FRANCIS	11-9-61	REVISED	DATE	ELEVON REQUIRED TO TRIM M=8.08
CHECK					
APR					
APR					THE BOEING COMPANY
TRACE	N.U.	11-9-61			

844-2050 D

D2-80065

PAGE 6.48

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ALBANENE 195L TRACING PAPER 68537

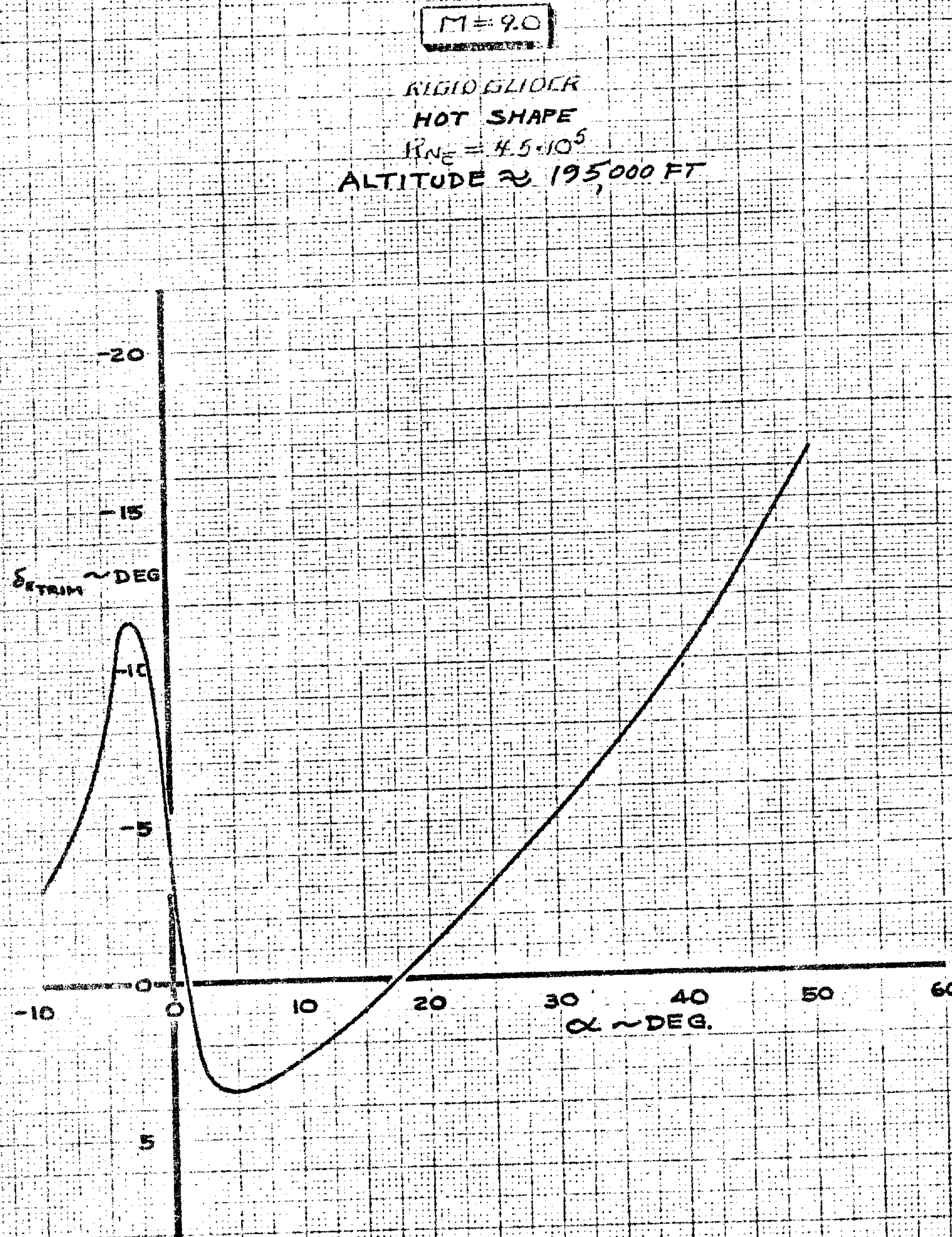

FIG. 6.42

			REVISED	DATE		
CALC	J.L. FRANCIS	12-11-1			ELEVON REQUIRED TO TRIM M = 9.0 LOW $R_{N_{\bar{c}}}$	844-2050 D
CHECK			12-27			D2-80065
APR					THE BOEING COMPANY	PAGE 6.49
APR						

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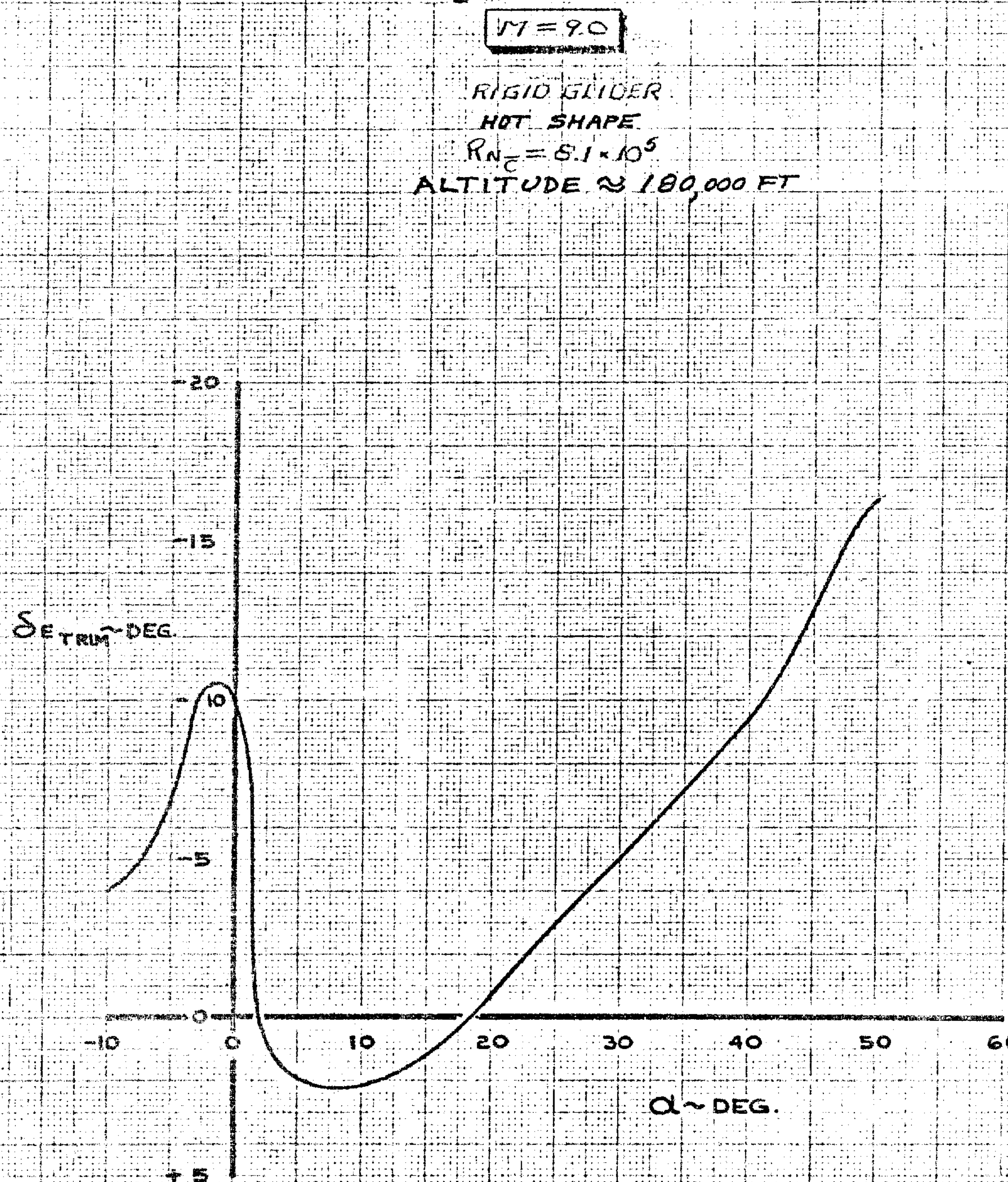

FIG. 6.43

CALC	J.L.FRANCIS	11-10-61	REVISED	DATE	ELEVON REQUIRED TO TRIM M = 9.0	844-2050 D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.50
DRN	N.D.	11-10-61				

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US 4013 6000

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M = 11.0

RIGID GLIDER
HOT SHAPE
$R_{N_c} = 4.5 \times 10^5$
ALTITUDE ≈ 195,000 FT.

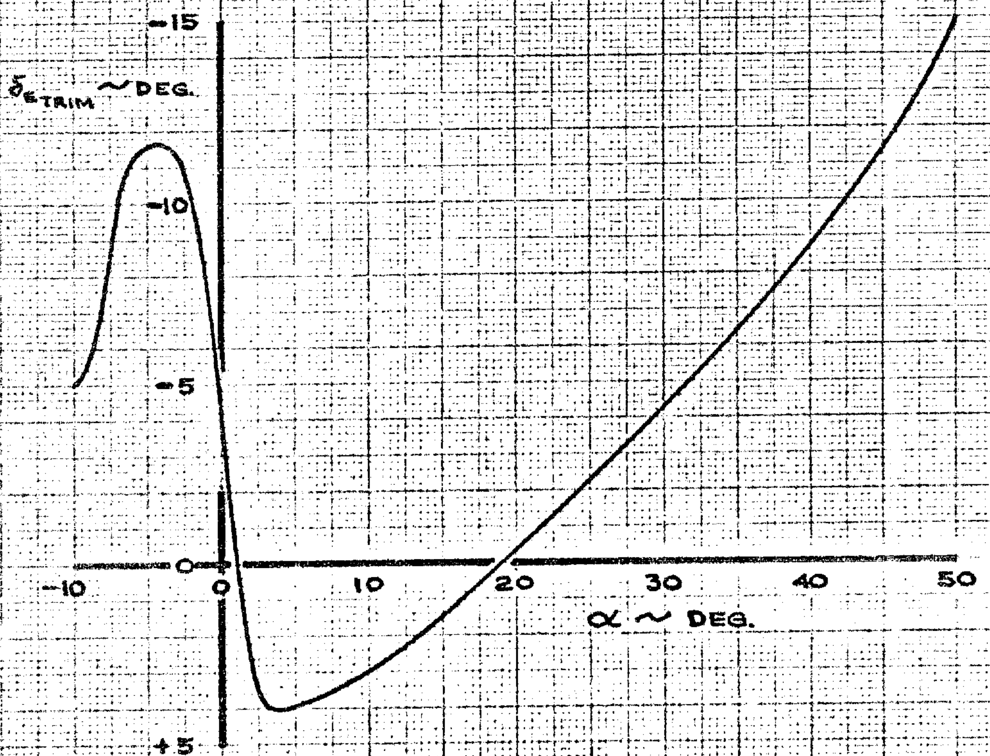

FIG. 6.44

CALC	J.L. FRANCIS	11/14/61	REVISED	DATE	ELEVON REQUIRED TO TRIM M = 11.0	844-2050 D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.51
APR						

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U3 4013 8000

$M=16.0$

RIGID GLIDER
HOT SHAPE
$R_{N_Z} = .164 \times 10^6$
ALTITUDE ≈ 236,000 FT.

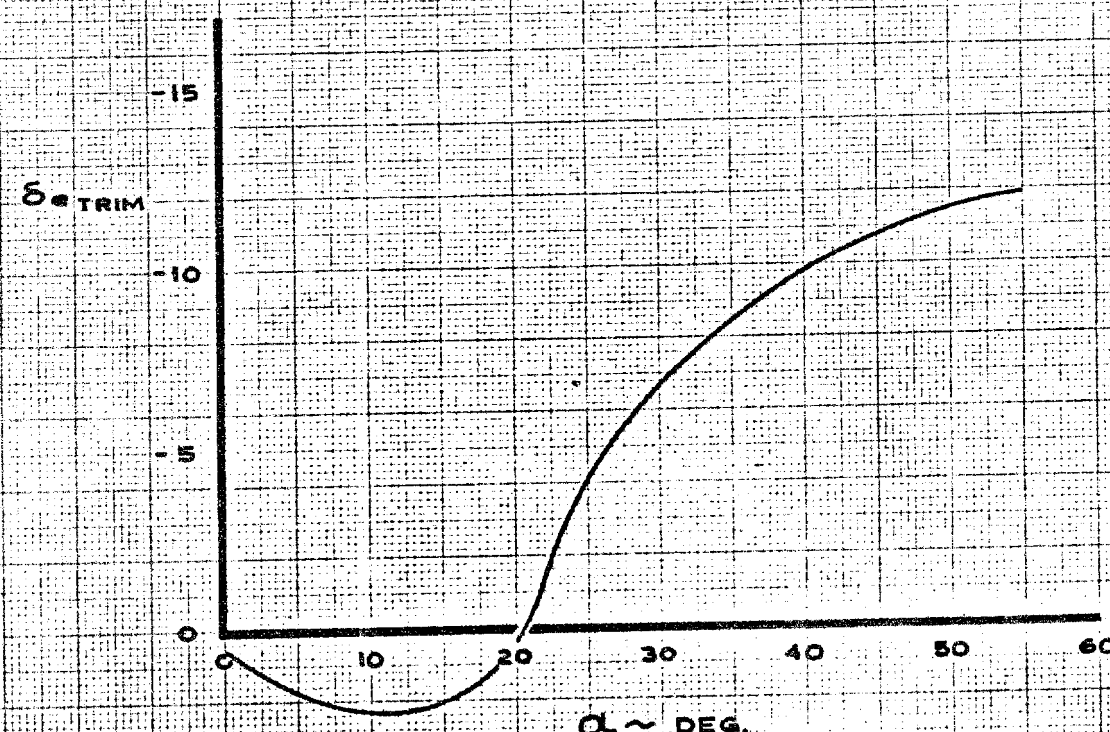

FIG. 6.45

CALC	Emf	11/10/61	REVISED	DATE
CHECK			12-22-61	
APR				
APR				
TRACE				

ELEVON REQUIRED TO TRIM
$M=16.0$

THE BOEING COMPANY

844-2050 D

D2-80065

PAGE 6.52

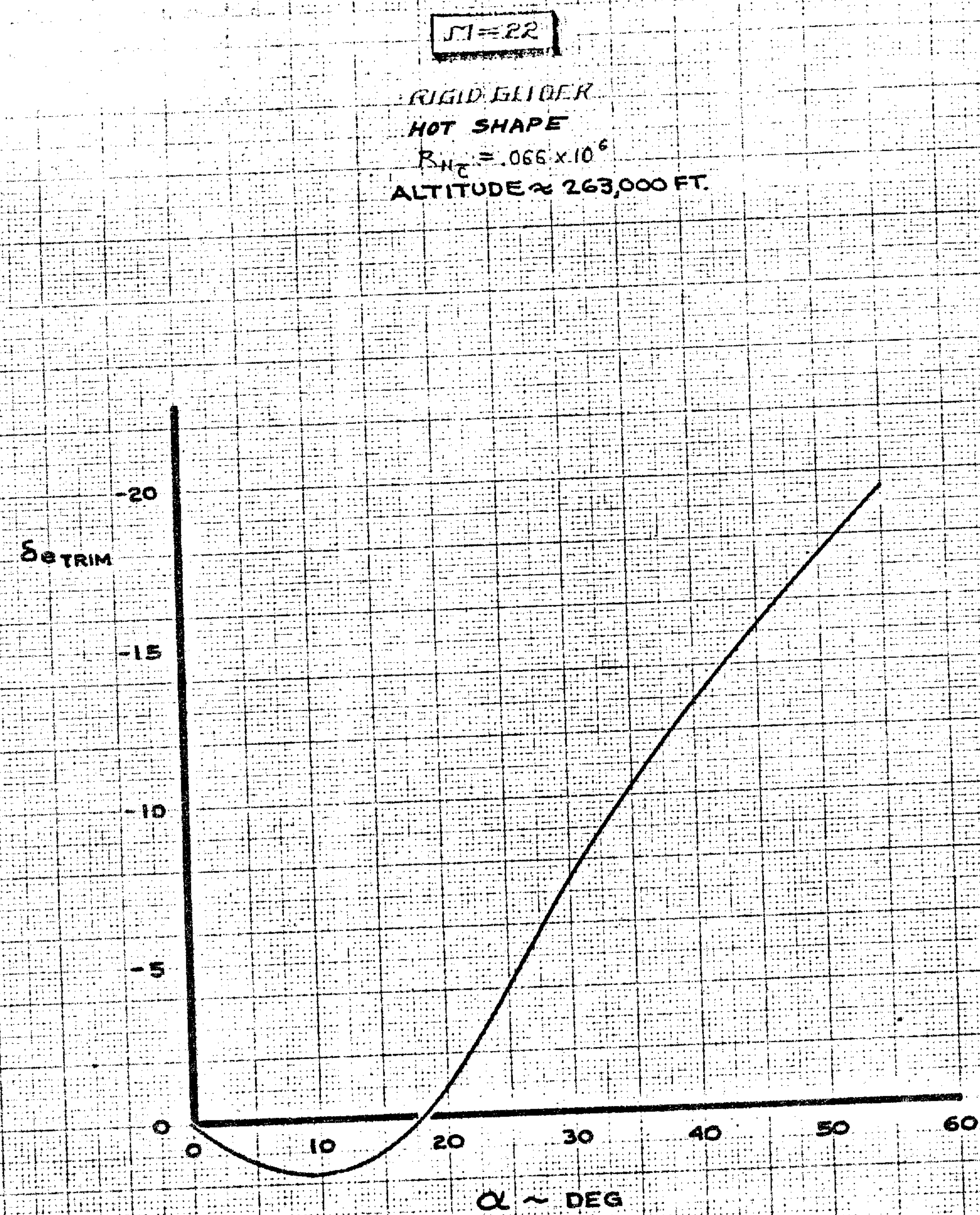

FIG. 6-46

CALC	Emg	11/8/61	REVISED	DATE	ELEVON REQUIRED TO TRIM M=22	844-2050 D
CHECK						DR-80065
APR					THE BOEING COMPANY	PAGE 6.53
APR						

TRACK

US 4013 8000

6.46

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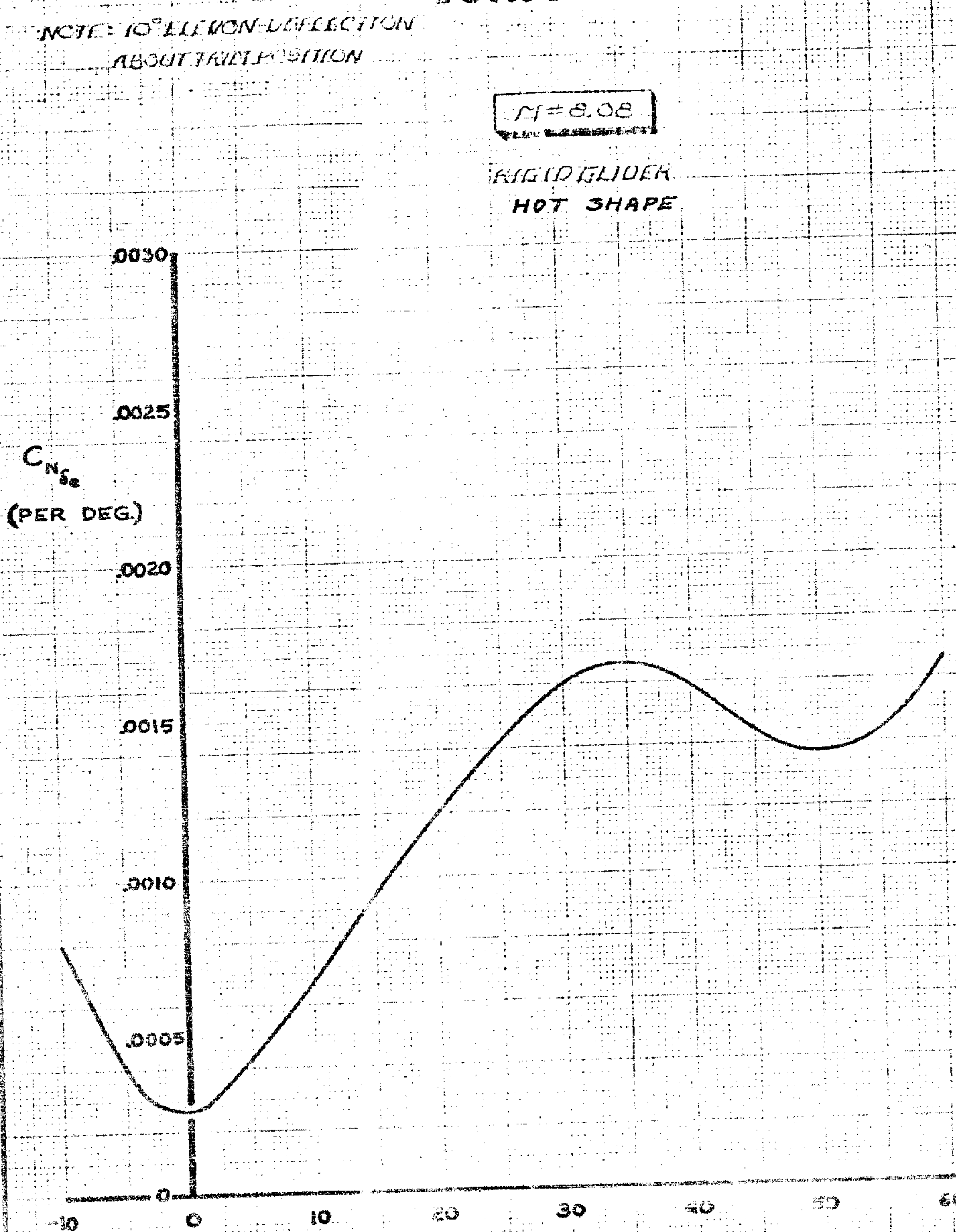

FIG. 6.47

CALC	GDR	11-?-76	REVISED	DATE	EFFECT OF ELEVON ON NORMAL FORCE M = 8.08	2050 D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.54
APR						

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US 4013 8000

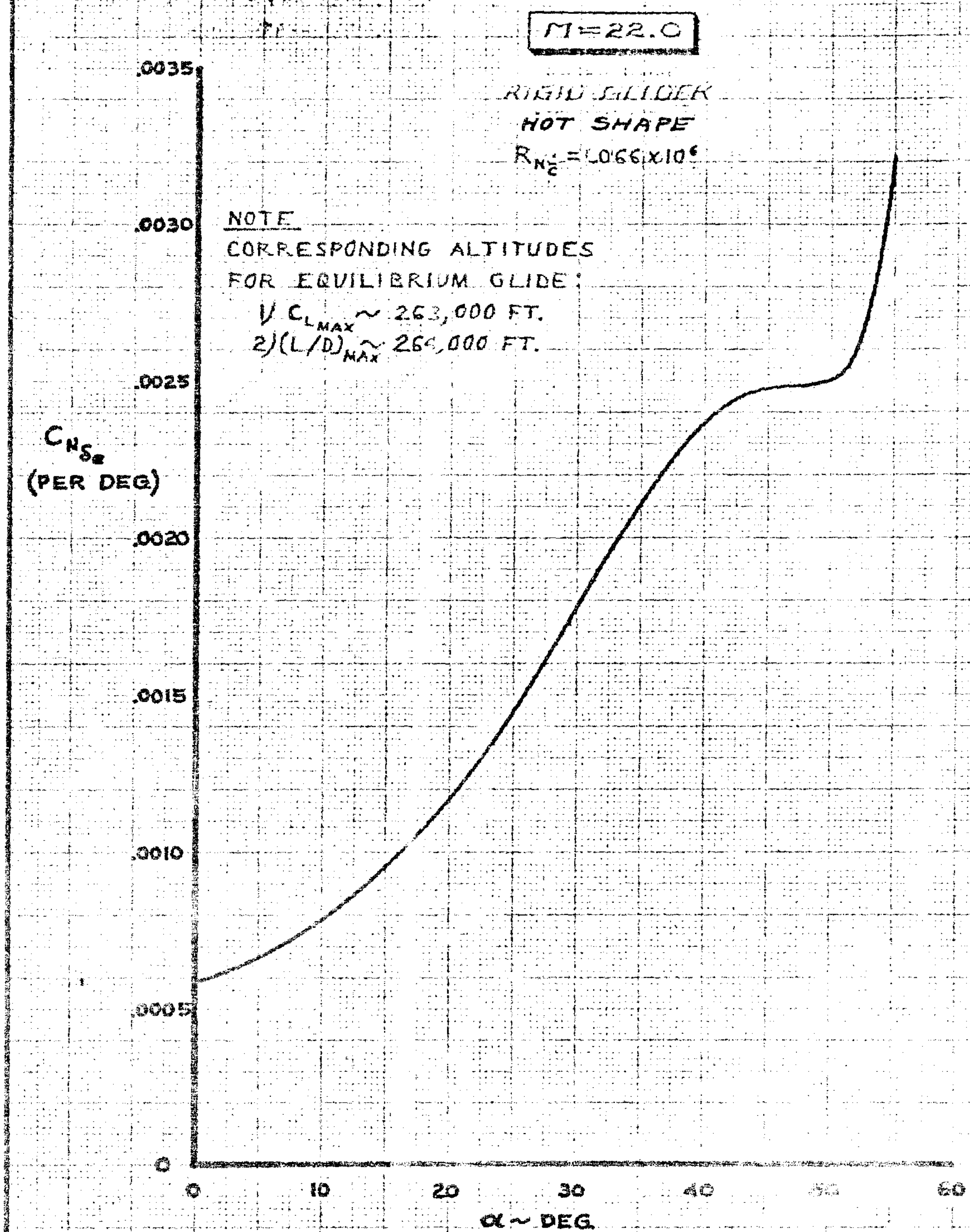

FIG. 6.48

CALC		REVISED	DATE
CHECK			
APR			
APR			

EFFECT OF ELEVON ON NORMAL FORCE M=22.0

THE BOEING COMPANY

844-2050 D

D2-8065

PAGE 6.55

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US 4013 8000

M = 6.0

NOTE: SLOPES TAKEN AT TRIM δ_E

RIGID GLIDER
HOT SHAPE
$R_{N_E} = 8.1 \times 10^5$
ALTITUDE ≈ 165,000 FT.

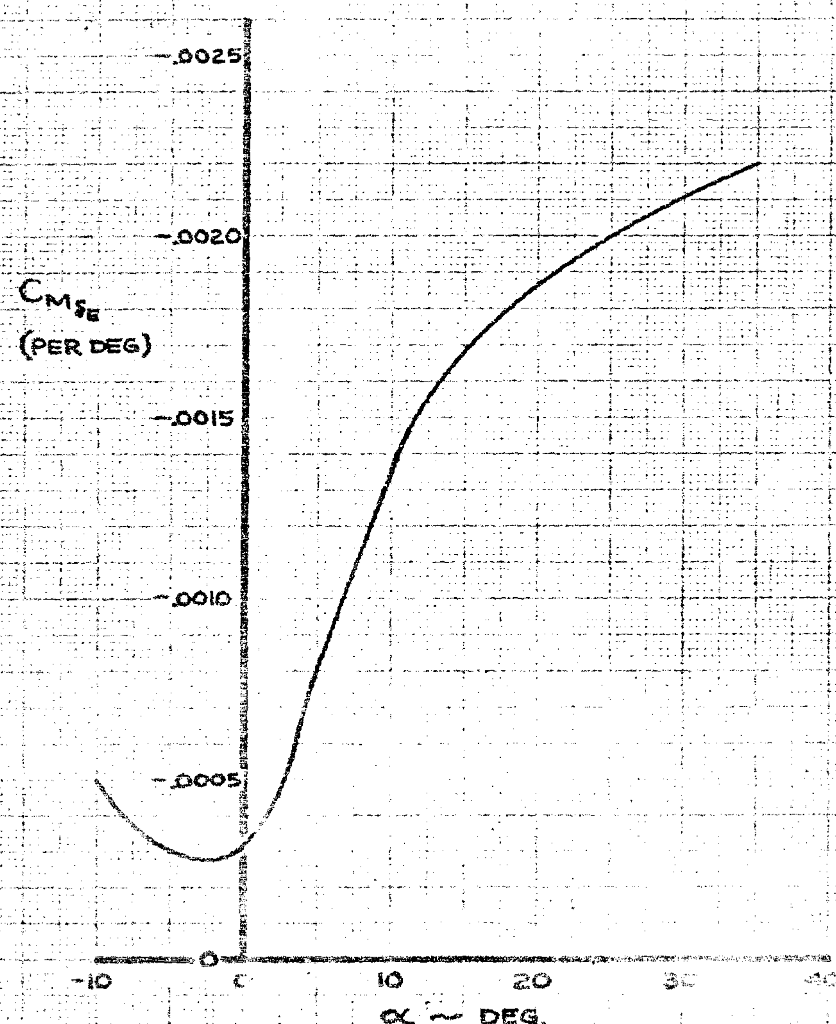

FIG. 6.49

CALC	U.L.F.		REVISED	DATE	ELEVON EFFECTIVENESS ABOUT TRIM M = 6.0	844-2050 D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.56
APR						

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M=8.0

NOTE: SLOPE TAKEN AT TRIM δ_E

RIGID GLIDER
HOT SHAPE

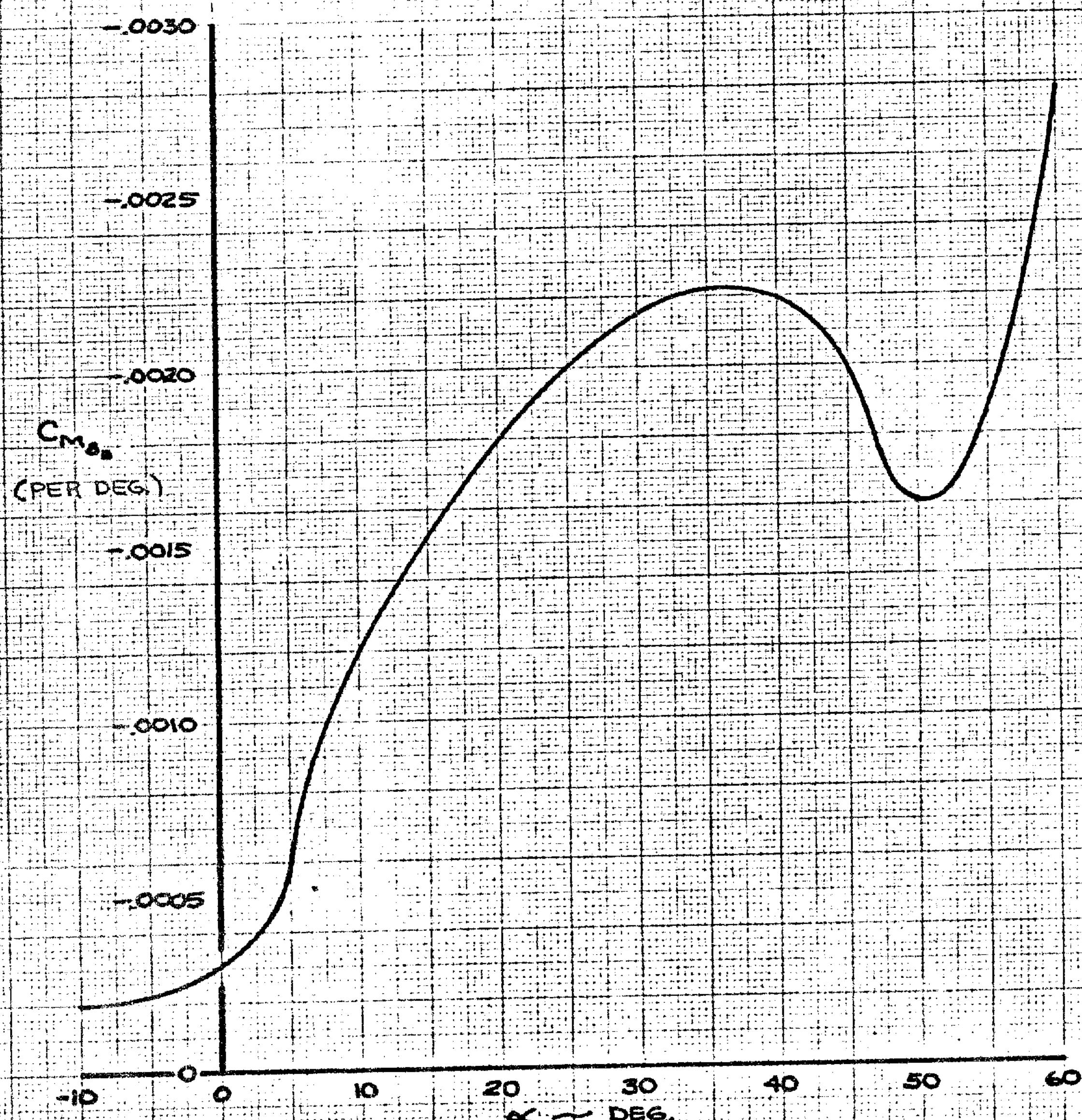

FIG. 6.50

CALC	J.L. FRANCIS	12/15/61	REVISED	DATE	ELEVON EFFECTIVENESS ABOUT TRIM M = 8.0	844-2050 D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.57

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U3 4013 8000 M=8

K·E ALBANENE 1961 TRACING PAPER 68587

M = 9.0

NOTE: SLOPE TAKEN
AT TRIM δ_e

RIGID GLIDER
HOT SHAPE
$R_{N_Z} = 4.5 \times 10^5$
ALTITUDE ≈ 195,000 FT.

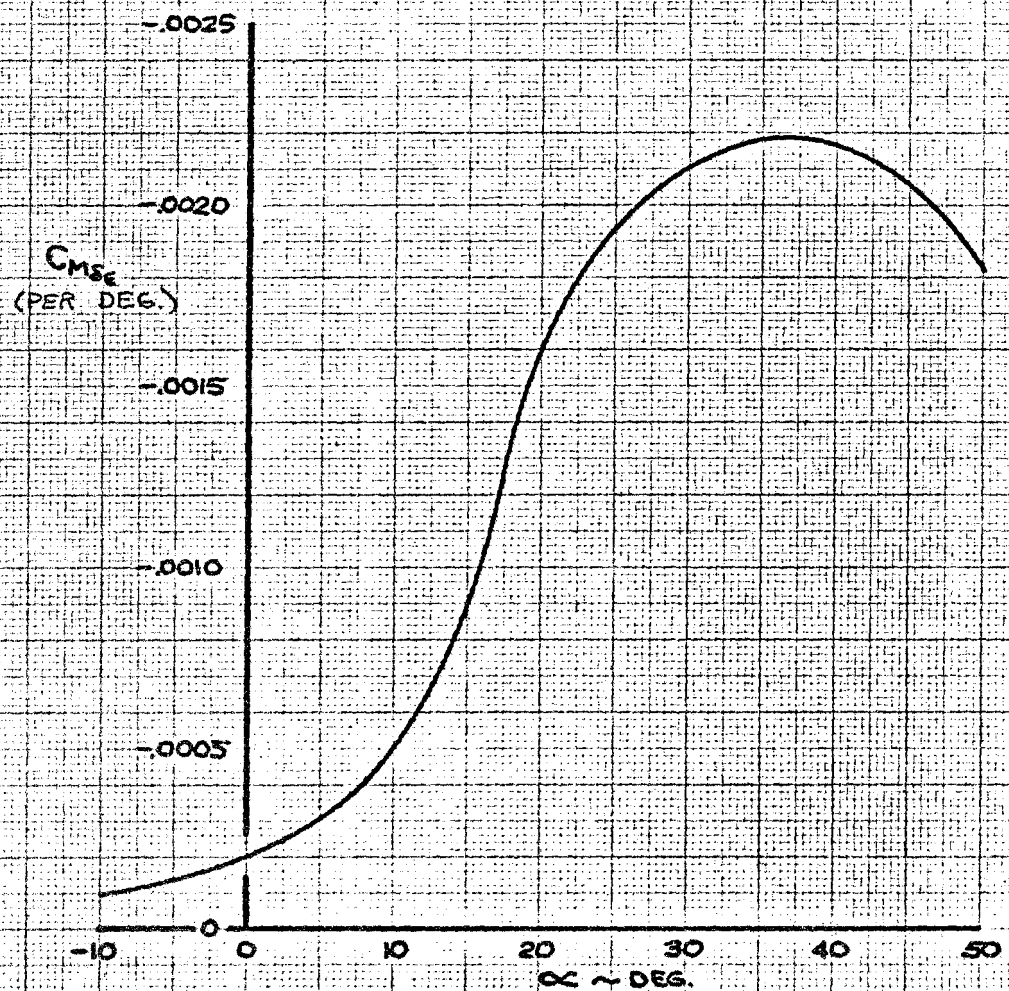

FIG. 6.51

CALC	J.L. FRANCIS	12/13/61	REVISED	DATE	ELEVON EFFECTIVENESS ABOUT TRIM M = 9.0 LOW R_{N_Z}	844-2050 D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.58
APR						

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US 4013 8000

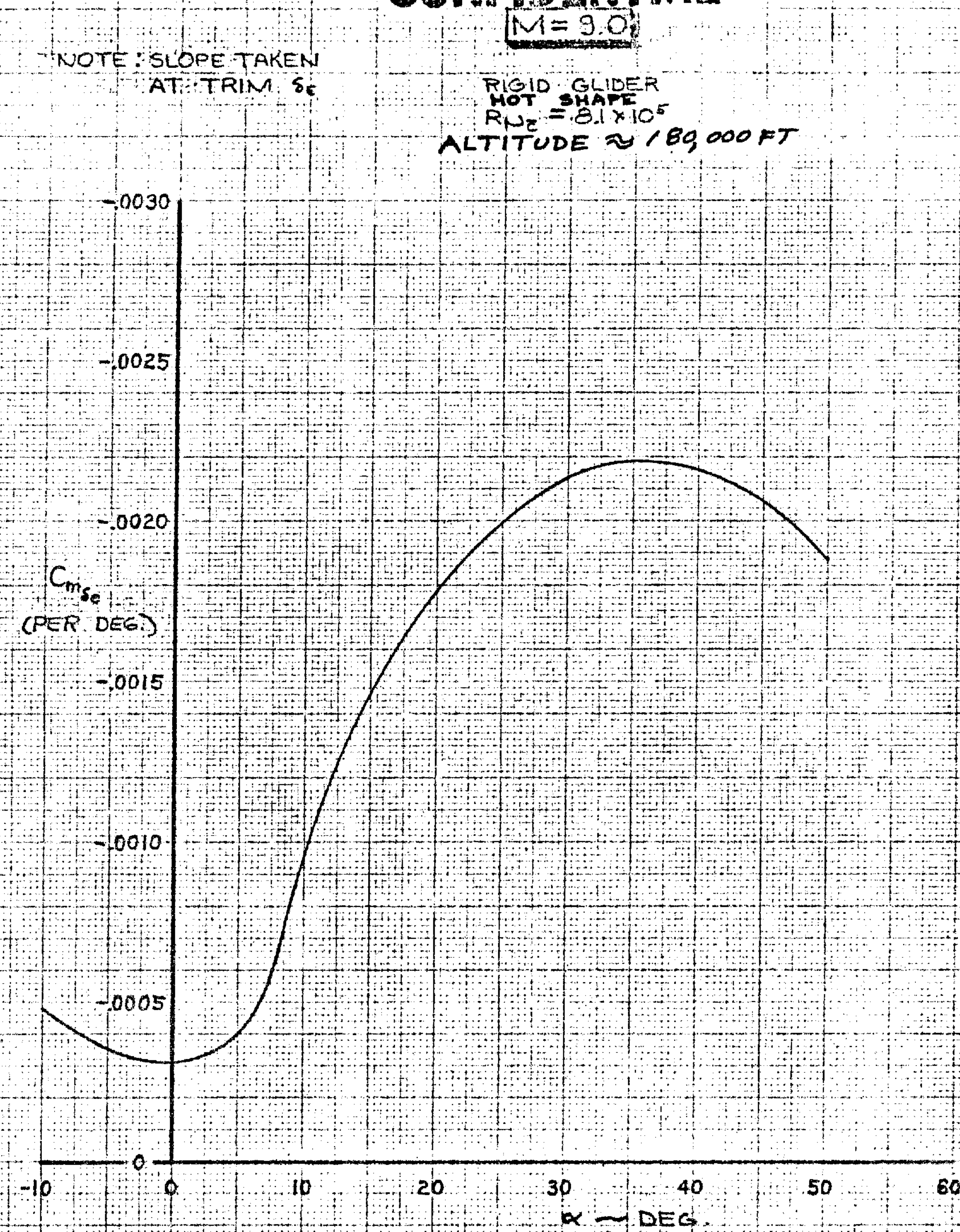

FIG. 6.52

			REVISED	DATE		
CALC	E.M.P.				ELEVON EFFECTIVENESS ABOUT TRIM M = 9.0	844-2050 D
CHECK			12-[illegible]			D2-80065
APR					THE BOEING COMPANY	PAGE 6.59
APR						

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US 4013 8000

K-E ALBANENE 195L TRACING PAPER 68587

M=11

NOTE: SLOPES TAKEN AT TRIM δ_e

RIGID GLIDER
HOT SHAPE
$R_{N_Z} = 4.5 \times 10^5$
ALTITUDE ≈ 195,000 FT

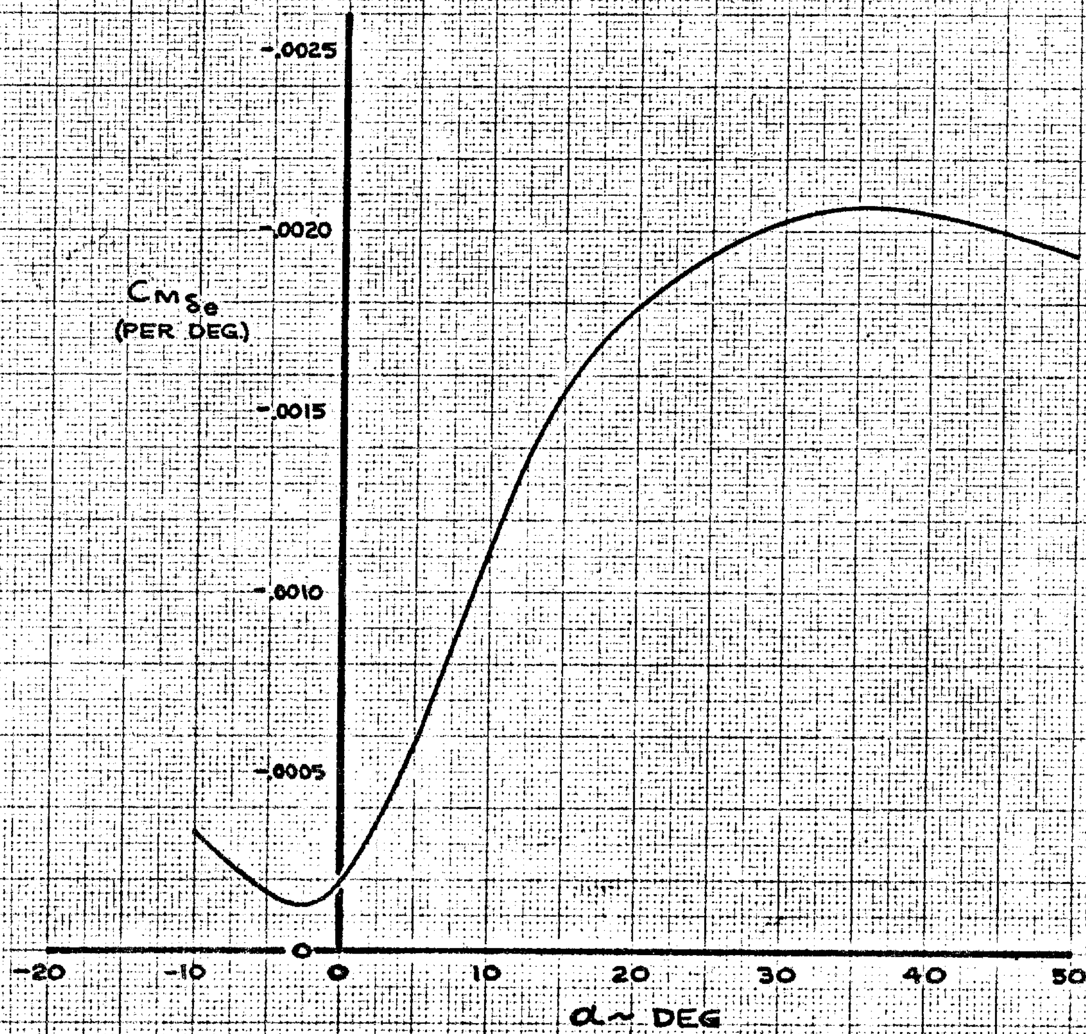

FIG. 6.53

CALC	E.M.P.		REVISED	DATE	ELEVON EFFECTIVENESS ABOUT TRIM M=11	844-2050 D
CHECK						
APR						D2-80065
APR					THE BOEING COMPANY	PAGE 6.60
PLOT	NU					

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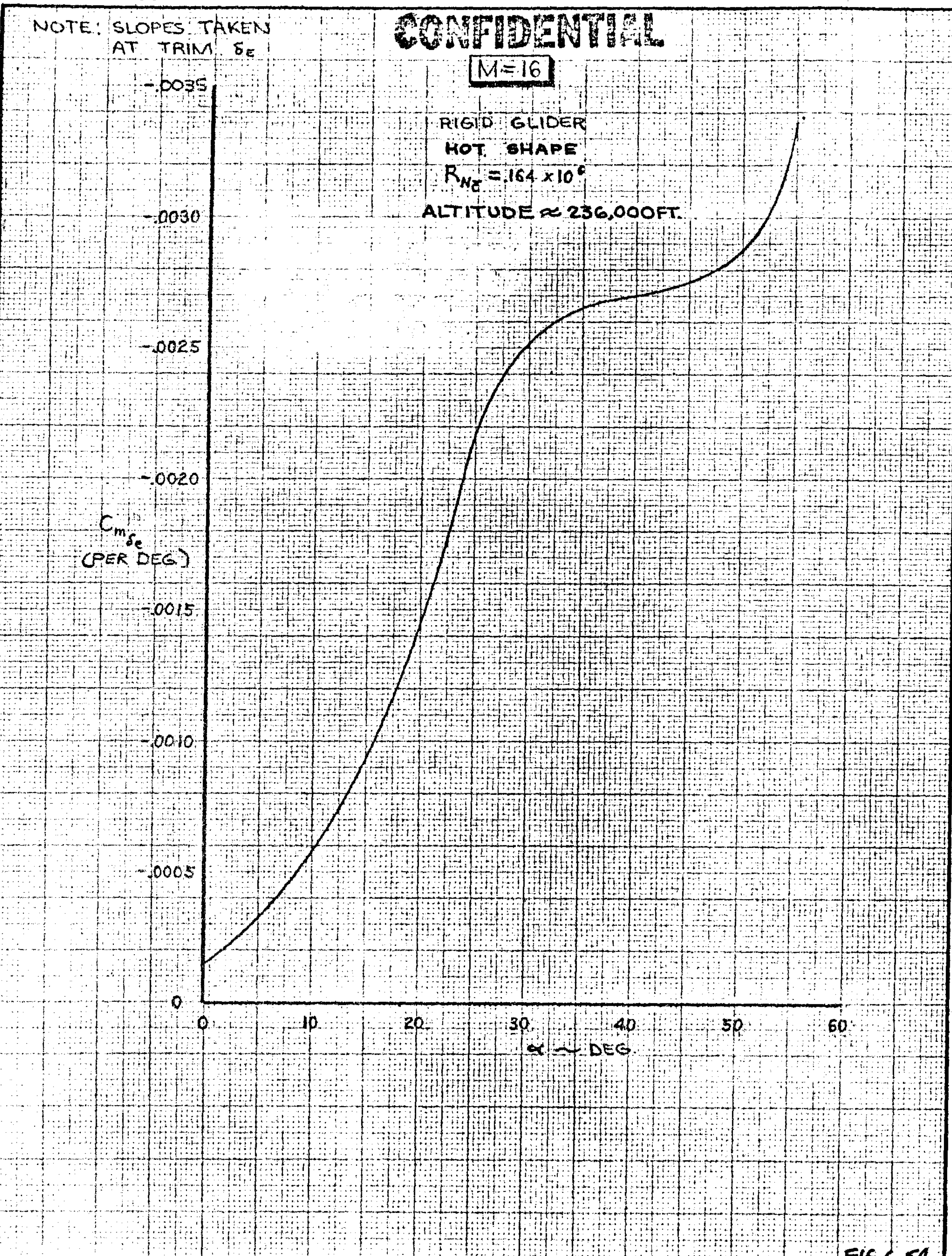

FIG. 6.54

CALC	E.M.P.		REVISED	DATE	ELEVON EFFECTIVENESS ABOUT TRIM M = 16	844-2050 D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.61

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U3 4013 8000

R-E ALBANENE 106L TRACING PAPER 68587

NOTE: SLOPES TAKEN AT TRIM δ_e

M=22

RIGID GLIDER
HOT SHAPE
$R_{N_Z} = .066 \times 10^6$
ALTITUDE ≈ 263,000 FT.

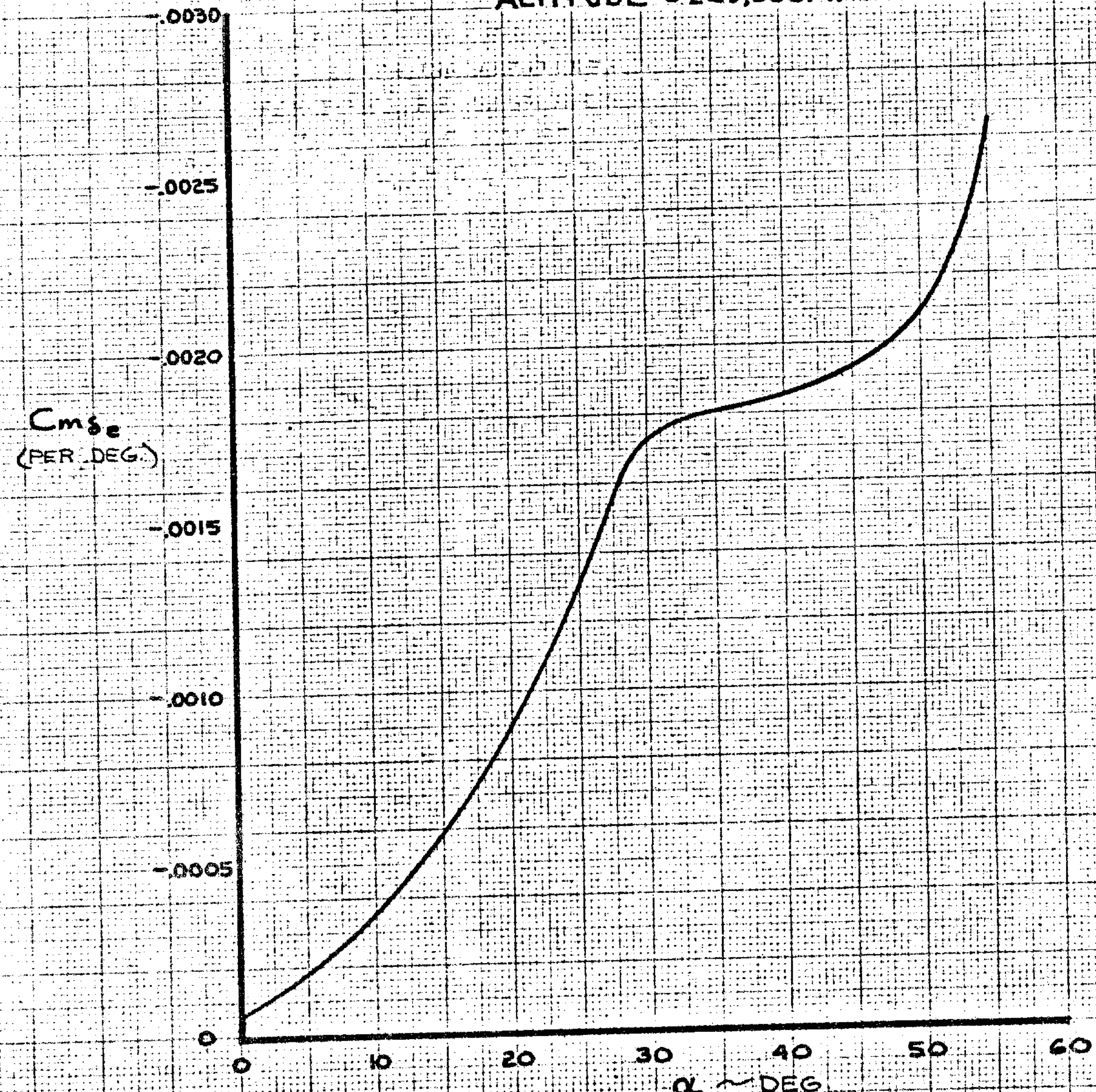

FIG. 6.55

6.54

CALC	E.M.P.		REVISED	DATE	ELEVON EFFECTIVENESS ABOUT TRIM M = 22	844-2050 D
CHECK			12-20-?			D2-80066
APR					THE BOEING COMPANY	PAGE 6.62
APR						

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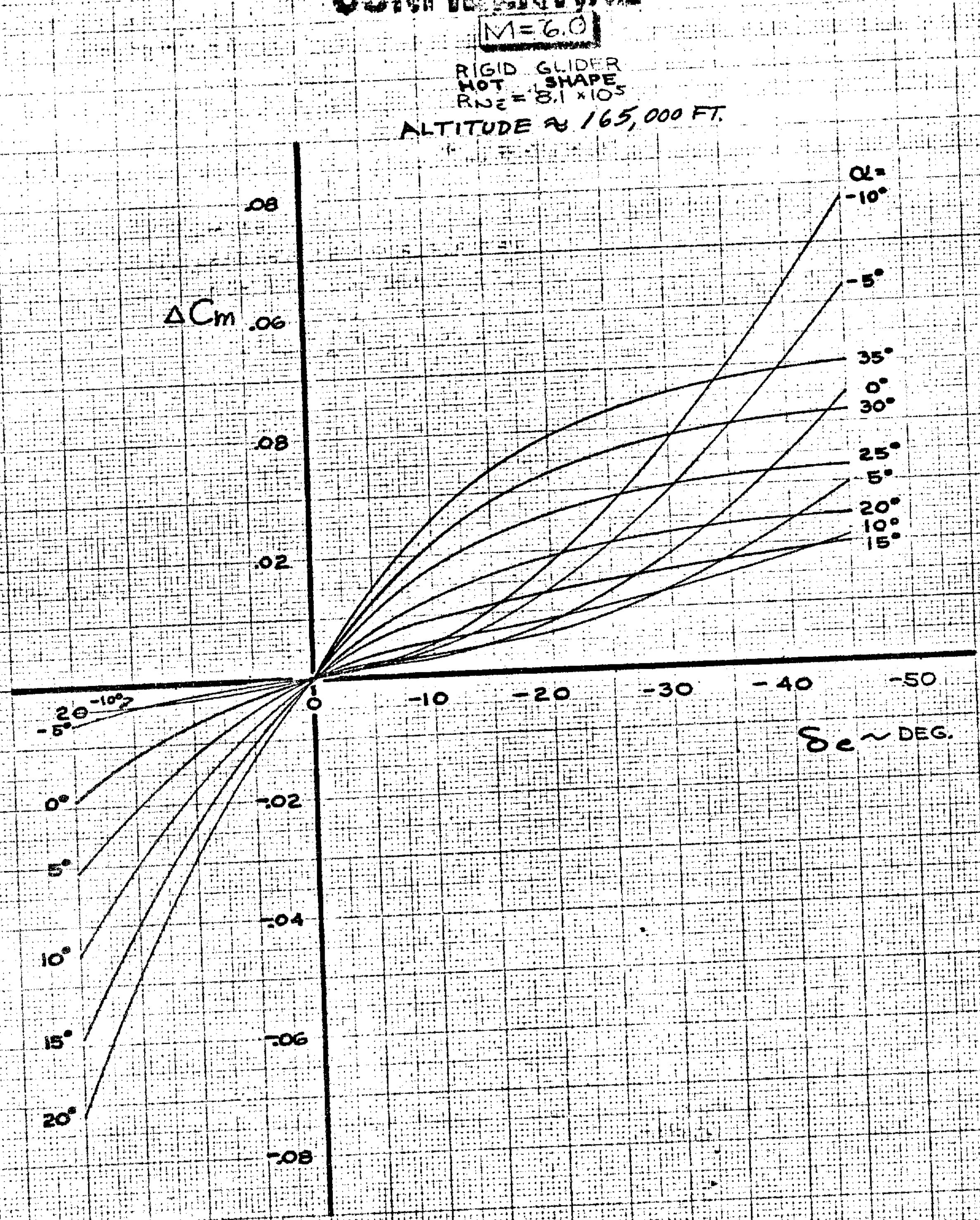

FIG. 6.56

CALC	N.O.		REVISED	DATE	ELEVON EFFECTIVENESS M. = 6.0	844-2050 D
CHECK						D2-80066
APR					THE BOEING COMPANY	PAGE 6.63
APR						

ALBANENE 195L TRACING PAPER 68587

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M = 8.0

RIGID GLIDER
HOT SHAPE

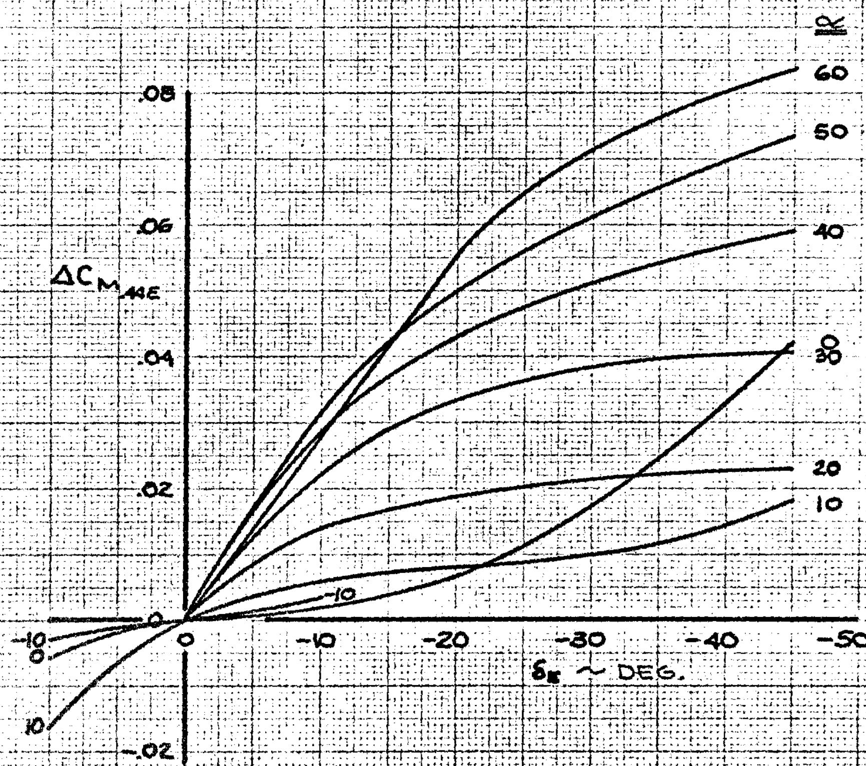

FIG. 6.57

CALC	J.L. Francis	12/13/61	REVISED	DATE	ELEVON EFFECTIVENESS M = 8.0	844-2050 D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.64

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US 4013 8000 M = 8 K+E ALBANENE 195L TRACING PAPER 68587

M = 9.0

RIGID GLIDER
HOT SHAPE
R_{N_Z} = 4.5 × 10⁵

ALTITUDE ≈ 195,000 FT

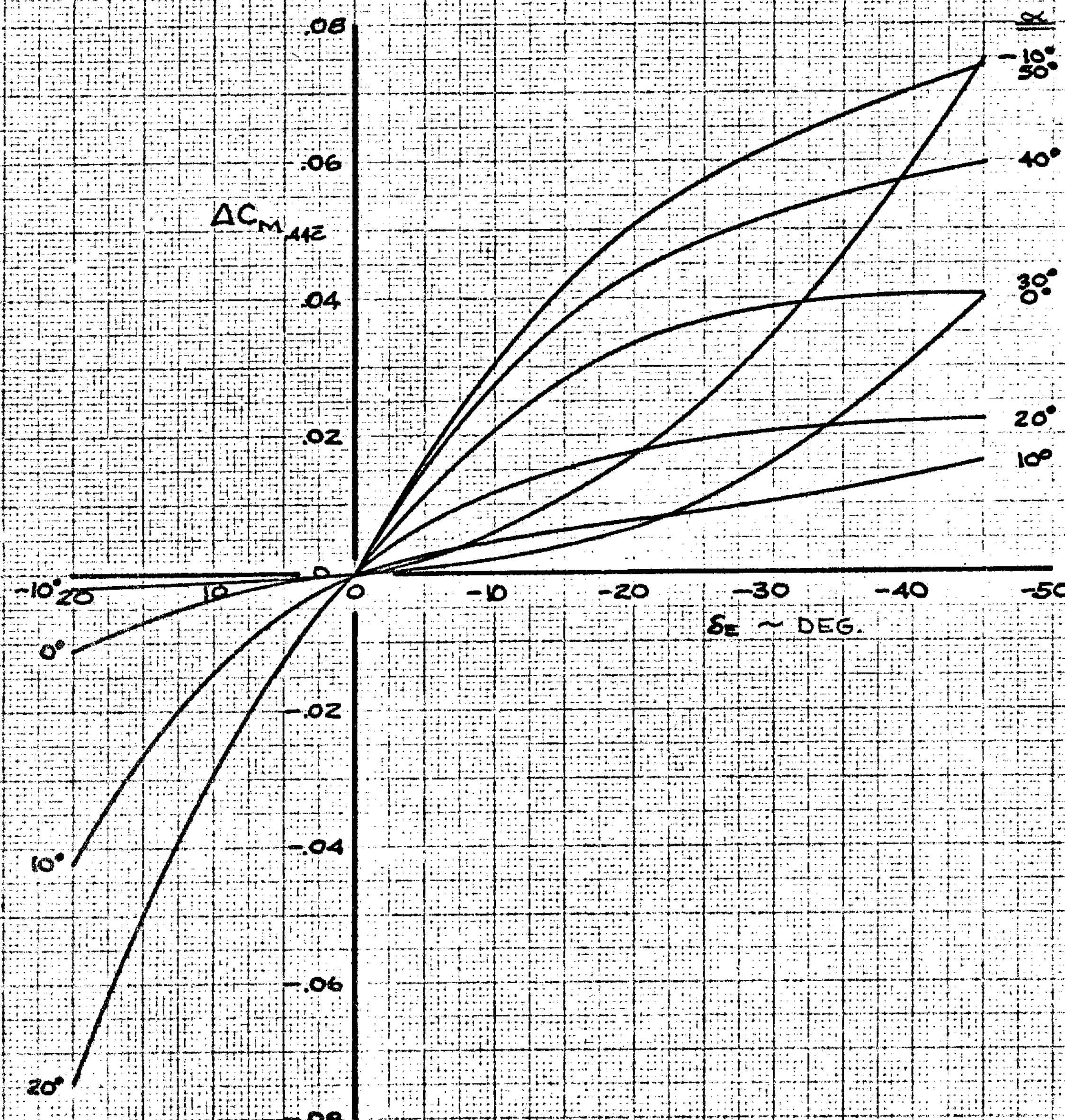

FIG. 6.58

CALC	J.L. FRANCIS	12/13/61	REVISED	DATE	ELEVON EFFECTIVENESS M = 9.0 LOW R_{N_Z}	844-2050.0
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.65
APR						

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U3 4013 8000 M=9 R_{N_Z} = 4.5 × 10⁵ K-E ALBANENE 196L TRACING PAPER 60629

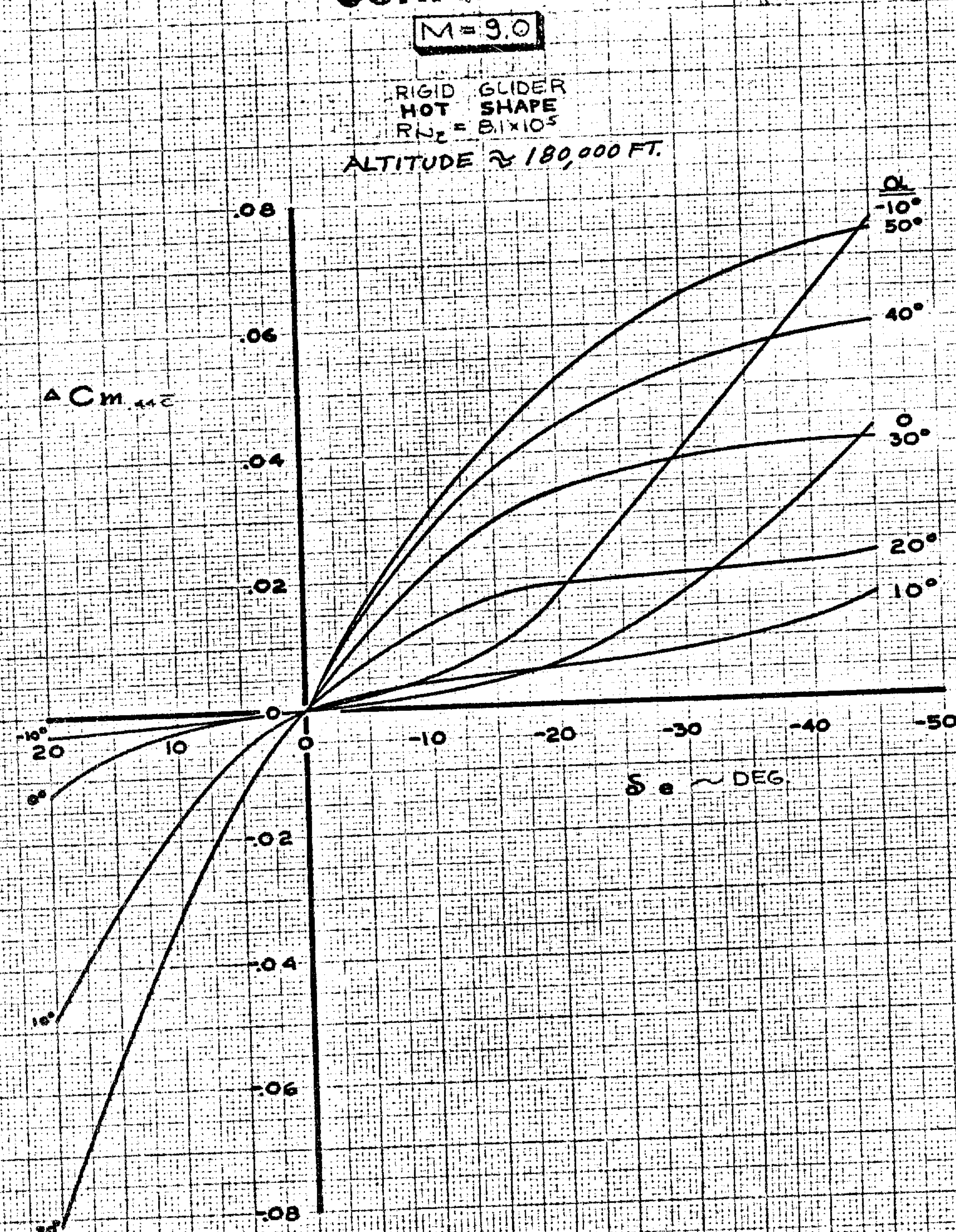

FIG. 6.59

CALC	G.D.K.		REVISED	DATE	ELEVON EFFECTIVENESS M = 9.0	844-2050 D
CHECK			12 ...			D2-80065
APR					THE BOEING COMPANY	PAGE 6.66
APR						

U3 4013 8000

ALBANENE 186L TRACING PAPER 60629

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RIGID GLIDER
HOT SHAPE
$R_{N_L} = 4.5 \times 10^5$
ALTITUDE ≈ 195,000 FT.

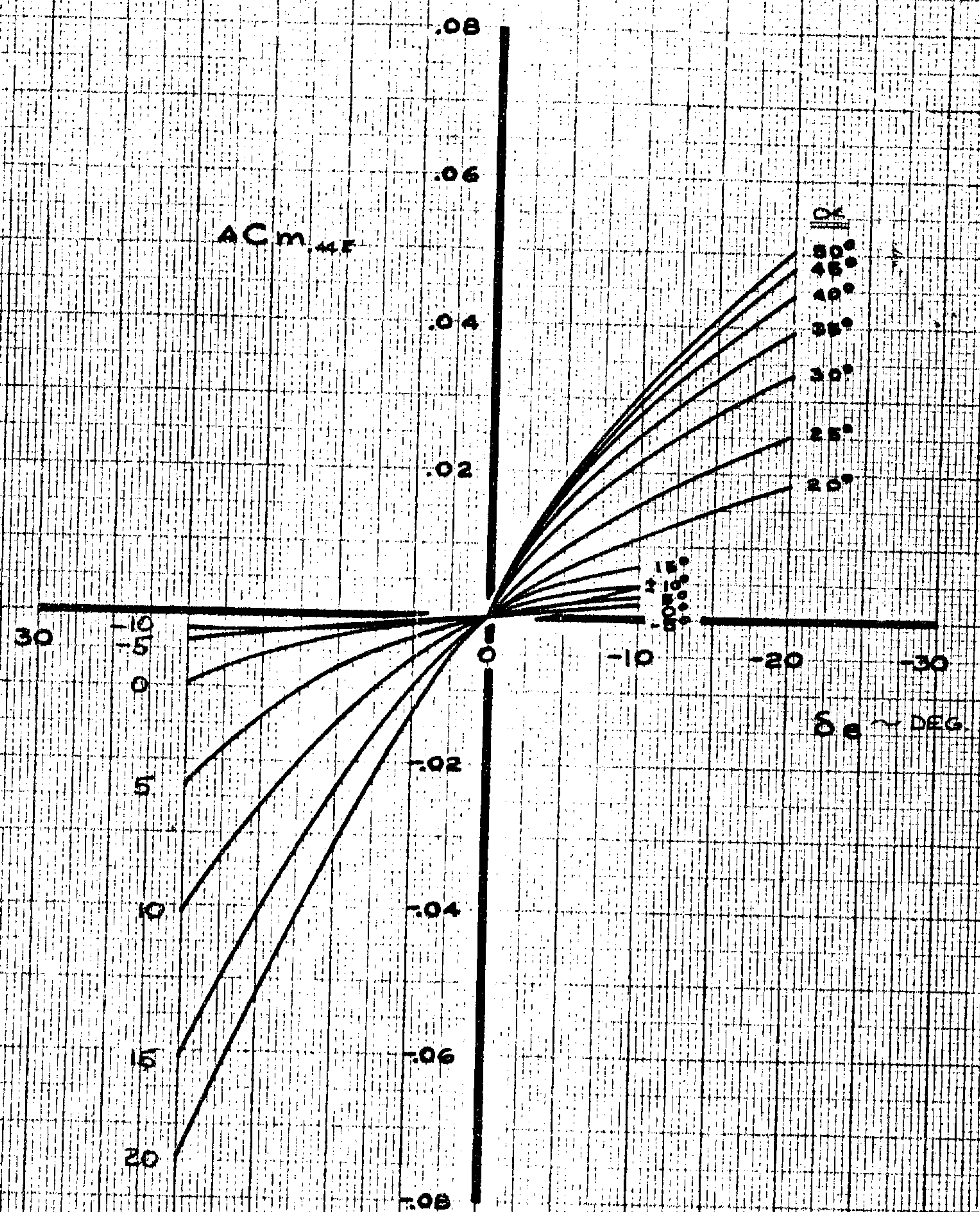

FIG. 6.60

CALC	E.M.P.		REVISED	DATE	ELEVON EFFECTIVENESS M = 11	644-2050 D
CHECK			12-20-1			
APR						D2-80065
APR					THE BOEING COMPANY	PAGE 6.67

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U3 4013 8000

K-E ALBANENE 196L TRACING PAPER 60629

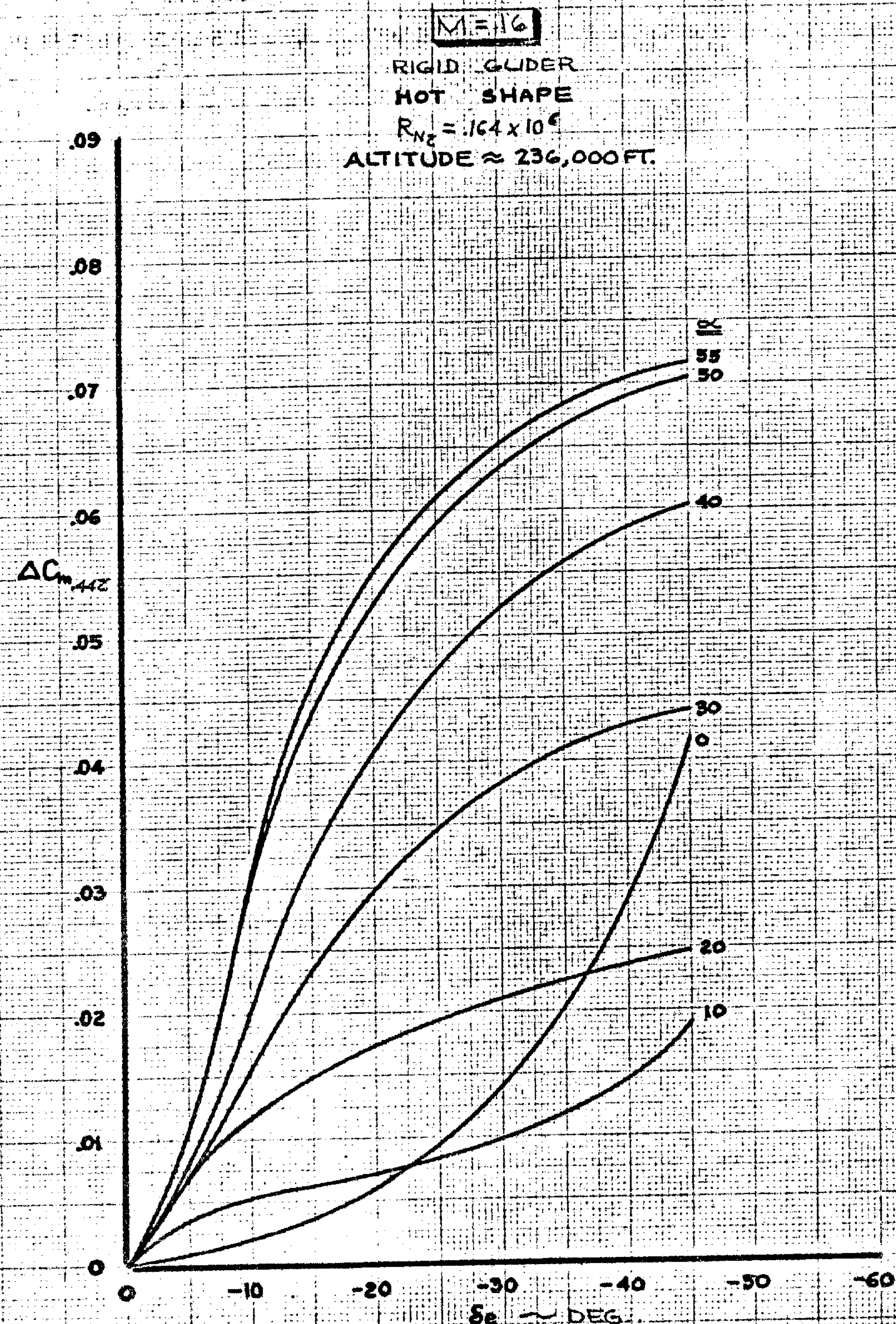

FIG. 6.61

CALC	E.M.P.		REVISED	DATE	ELEVON EFFECTIVENESS M = 16	844-2050 D
CHECK			J.L.F.	12/18/61		D2-80066
APR			12-20-1			PAGE 6.68
APR					THE BOEING COMPANY	

US 4013 8000

K-E ALBANENE 195L TRACING PAPER 68587

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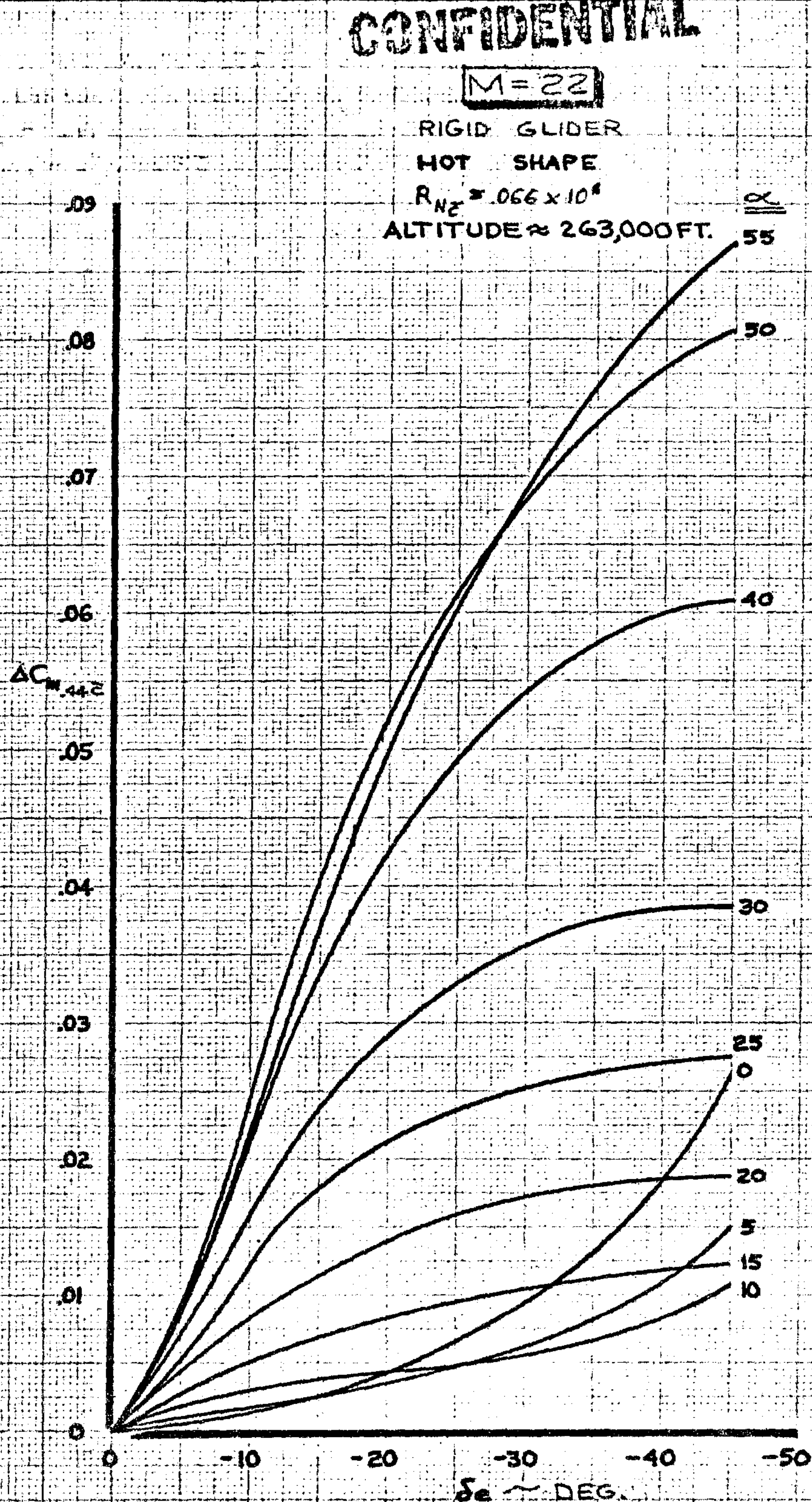

FIG. 6.62

CALC	E.M.P.		REVISED	DATE	ELEVON EFFECETIVENESS M = 22	844-2050 D
CHECK			12-2-61			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.69

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6.1.5 ELEVON AS AILERON - PITCH COUPLING

Effects on normal force and pitching moment of symmetrical elevon deflections about a trim position for subsonic and supersonic speeds are shown in Figure 6.63. These curves are based on wind tunnel data and are applicable through 4 degrees aileron deflection. At larger aileron deflections non-linear characteristics appear.

Hypersonic aileron-pitch coupling effects are shown in Figures 6.64 and 6.65. These curves are based on faired wind tunnel data and are assumed linear to 10 degrees of aileron deflection.

The substantial increase in $C_{m_{\delta_a}}$ from supersonic to hypersonic speeds, Figures 6.63 and 6.64, is attributed primarily to the range of aileron deflections from which the slopes of non linear data were taken. At hypersonic speeds where dynamic pressure is low, a given roll response requires large aileron deflections. Therefore it is more desirable for simulator data inputs to define $C_{m_{\delta_a}}$ over a larger range of aileron deflections.

More refined derivatives can be derived for hypersonic speeds from the data presented in Figures 6.56 through 6.62. Each elevon or aileron should be treated independently. The effect in pitch can be determined by taking one-half the incremental moment between the trimmed elevon position and the deflected aileron position. Summing these two increments algebraically gives the total aileron effect on pitching moment.

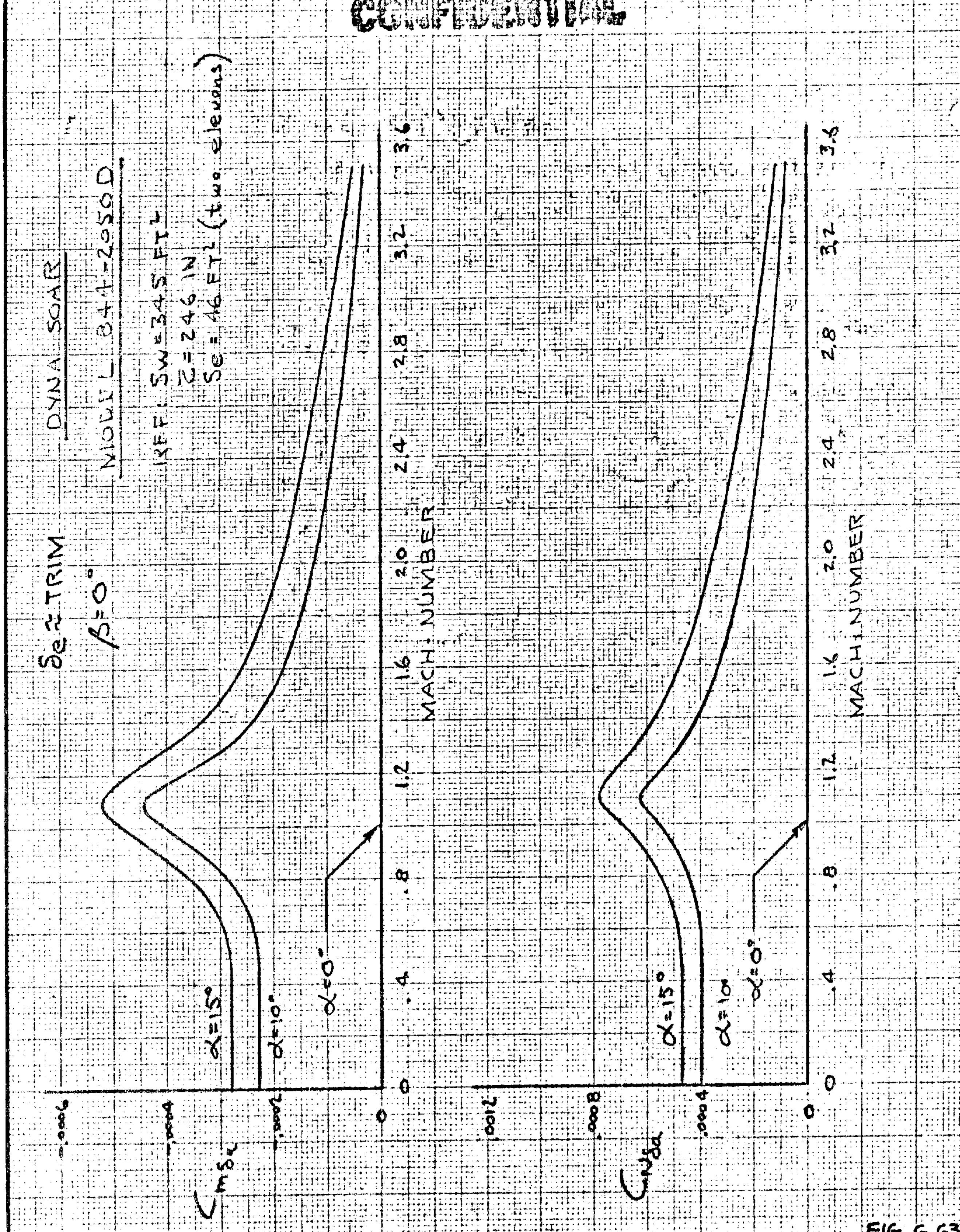

FIG. 6.63

CALC	EJH	12/15/1	REVISED	DATE	AILERON/PITCH COUPLING SUBSONIC THROUGH SUPERSONIC	844-2050D
CHECK			12-20-1			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.71

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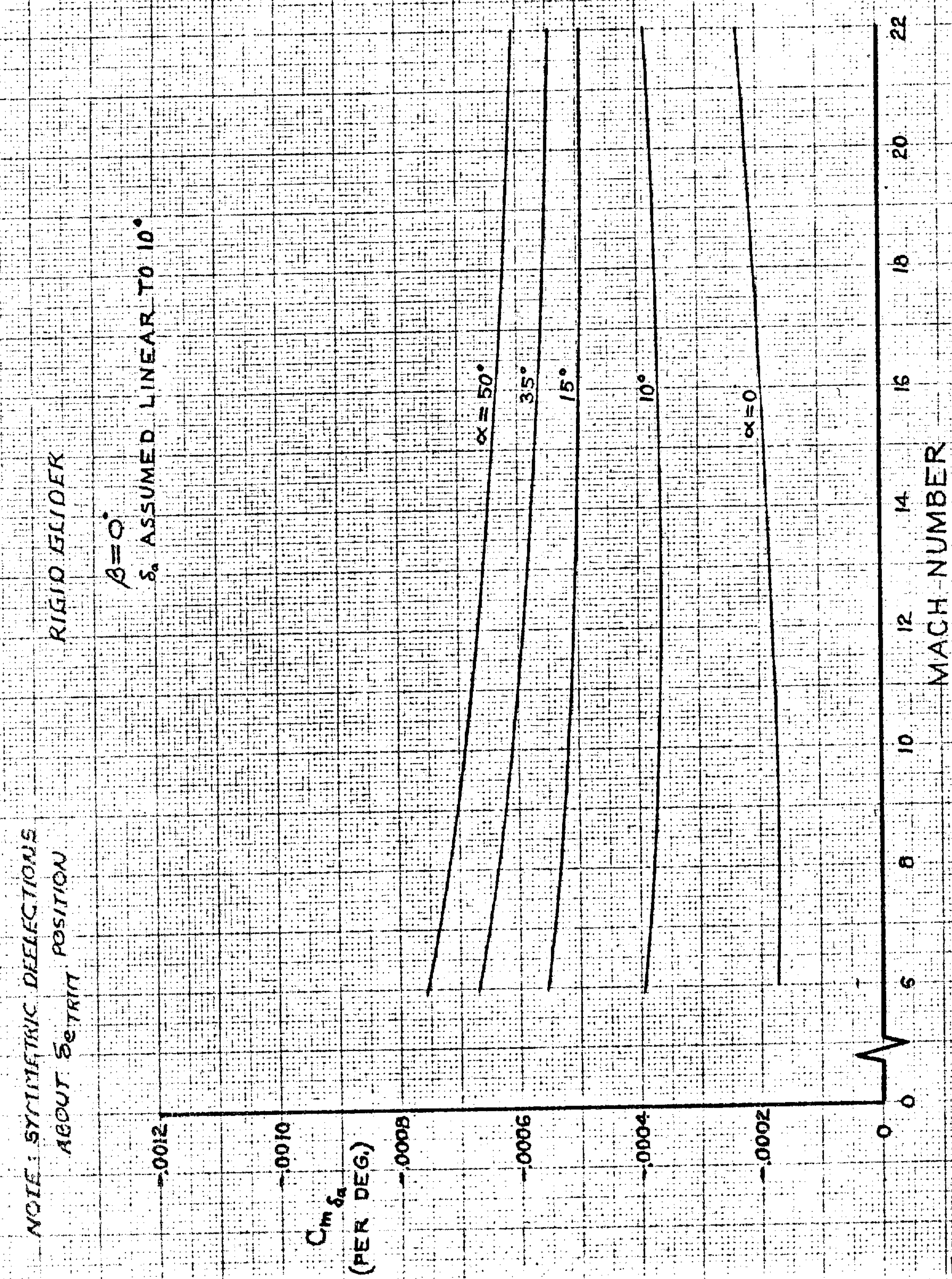

FIG. 6.64

CALC	NDK	12-12-61	REVISED	DATE	AILERON/PITCH COUPLING PITCHING MOMENT HYPERSONIC	844-2050D
CHECK			12-[illegible]			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.72

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US 4013 8000

K-E ALBANENE 196L TRACING PAPER 68587

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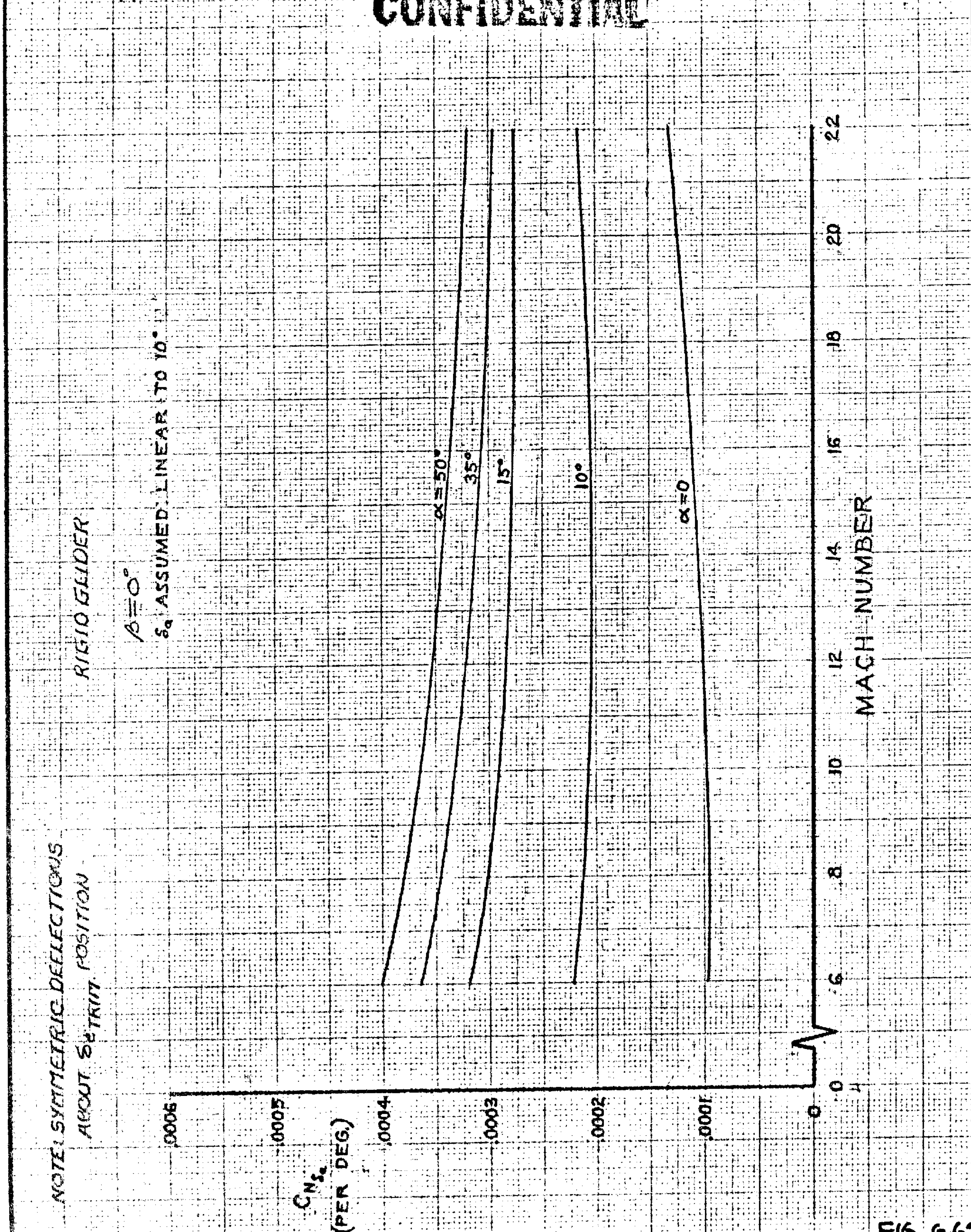

FIG. 6.65

CALC	GDK	12-12-61	REVISED	DATE	AILERON/PITCH COUPLING NORMAL FORCE HYPERSONIC	844-2050 D
CHECK			12-22-61			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.73

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6.1.6 ROTARY DERIVATIVES

Pitch damping derivative C_{m_q}, shown in Figure 6.66, was obtained from NASA reports of similar configurations. These data were also compared with linear theory which showed reasonable agreement at subsonic speeds but was nearly double the empirical value at supersonic speeds. Data from Langely Research Center Free Flight Wind Tunnel showing the effects of angle of attack and oscillation frequency on C_{m_q} and $C_{m_{\dot{\alpha}}}$ are shown in Figure 6.67. Additional theoretical and experimental work is planned to further define these derivatives.

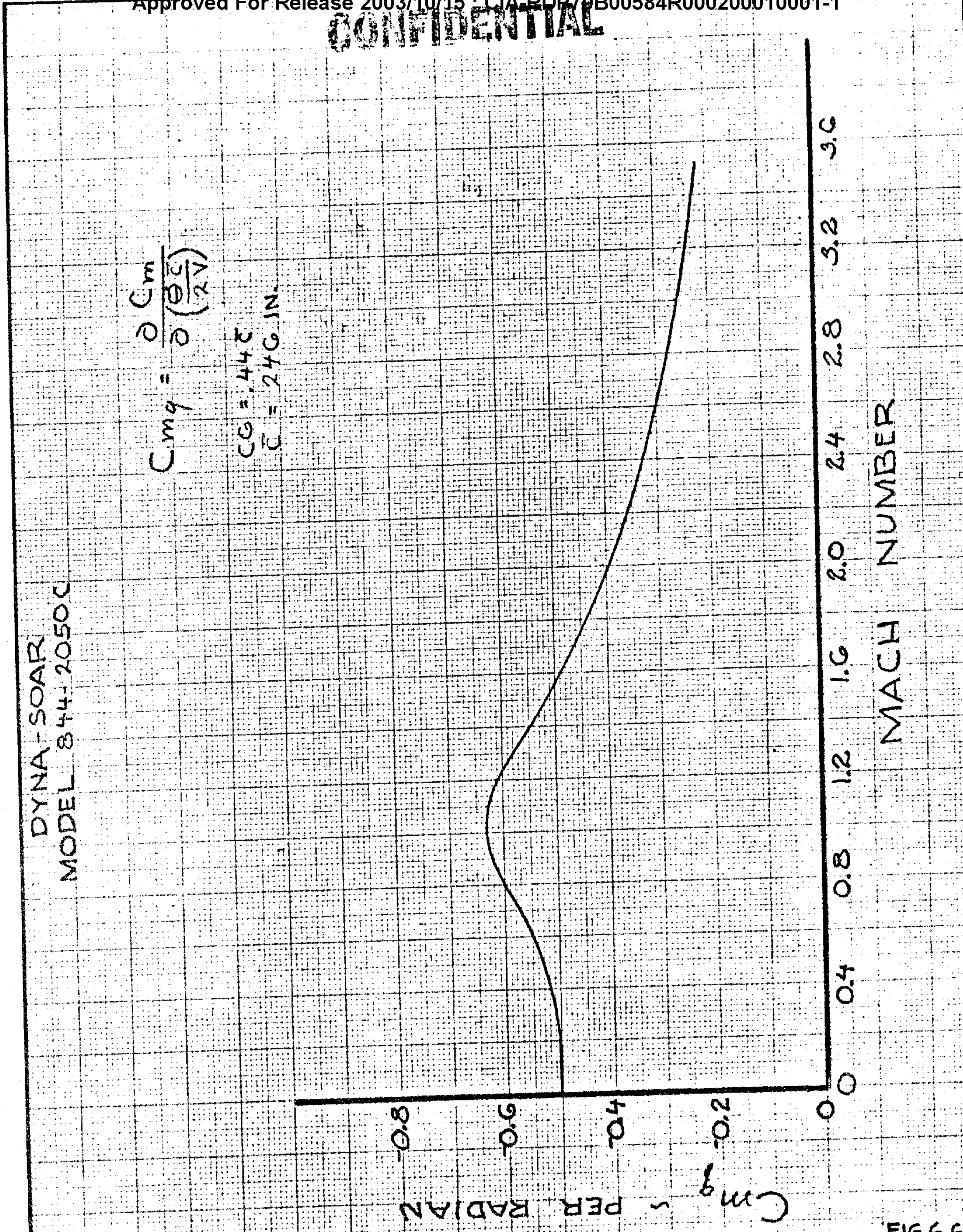

FIG. 6.66

CALC	SAKATA	3-30-1	REVISED	DATE	PITCHING MOMENT DUE TO PITCHING VELOCITY	844-20500
CHECK			12-20-1			D2-80066
APR					THE BOEING COMPANY	PAGE 6.75
APR						
TRACED		4-4				

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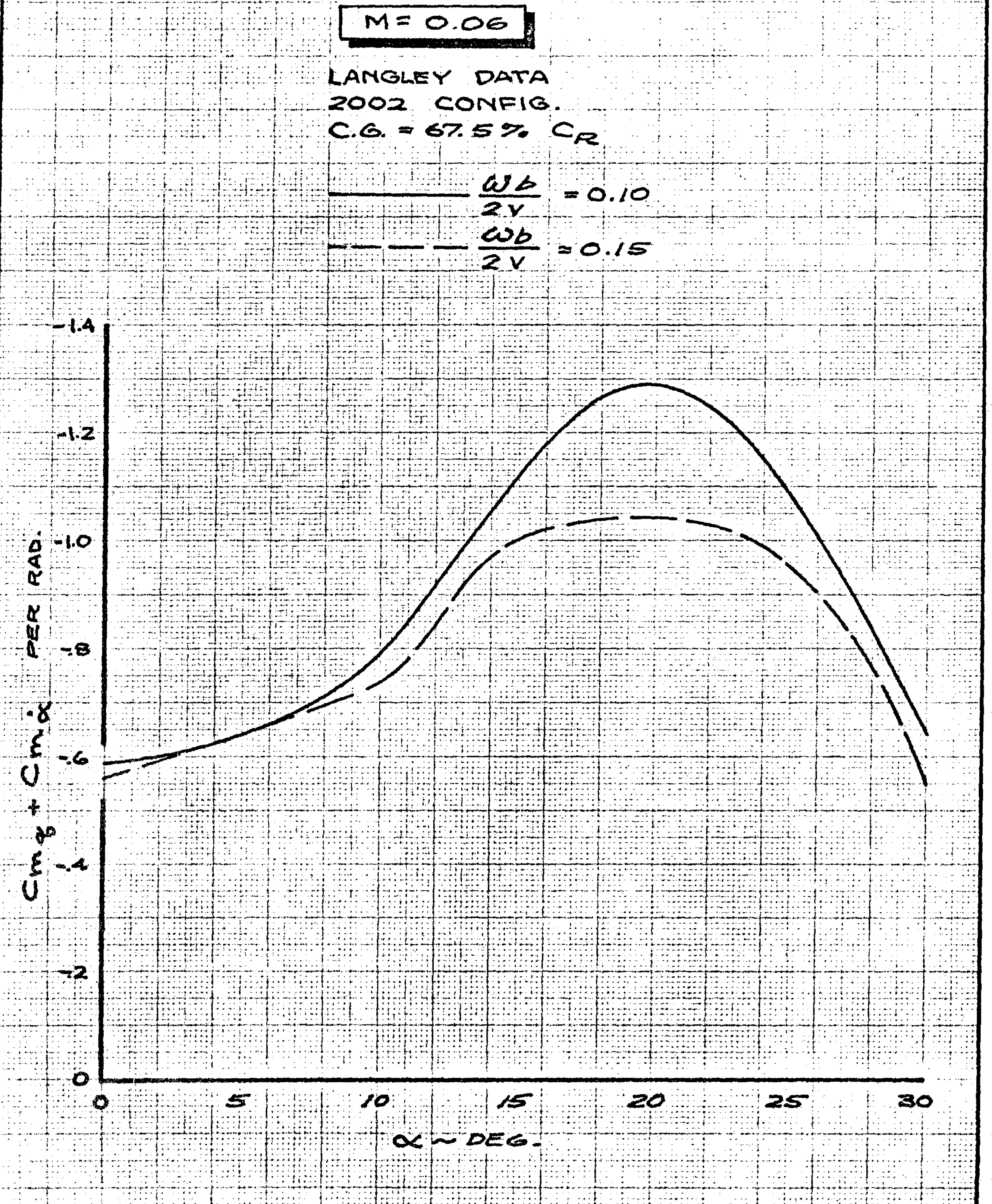

FIG. 6.67

CALC	SAHATA	3-30-61	REVISED	DATE	PITCHING MOMENT DUE TO PITCHING VELOCITY LOW SPEED	644-2050D
CHECK			12-2-61			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.76
DRN	R.RICE	12-1-61				

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6.1.7 ELEVON HINGE MOMENT CHARACTERISTICS

The elevon hinge moment coefficients are for the current glider configuration, 844-2050D.

The data used for the curves presented in Figures 6.68 through 6.88 consists of wind tunnel data obtained at the Boeing Transonic and Supersonic Tunnels, Tests BTWT 685 and BSWT 113 and then modified to the 844-2050D rigid glider.

The curves for the hinge moment derivatives C_{H_β}, $C_{H_{\delta e}}$ and C_{H_α}, as shown in Figures 6.68 through 6.70, and the curve for the coefficient C_{H_o}, as shown in Figure 6.71, summarize the change in the linearized coefficient data with a variation in Mach number. All data are based on an elevon 2 Ma value equal to 1222 in-ft. sq. and an area equal to 22.9 ft. sq. per elevon.

Detailed elevon hinge moment coefficients and their variation with elevon deflection (δ_e) and glider angle of attack (α) are shown in Figures 6.72 through 6.80. These data are not linear for the transonic speed range of Mach number equal to .90 through 1.1.

Figures 6.81 through 6.88 show the relationship between elevon trim position and elevon float position and may be used to determine the elevon actuator load reversal points. The elevon required to trim information is a repeat of data in section 6.1, Longitudinal Stability and Control.

12-20-1

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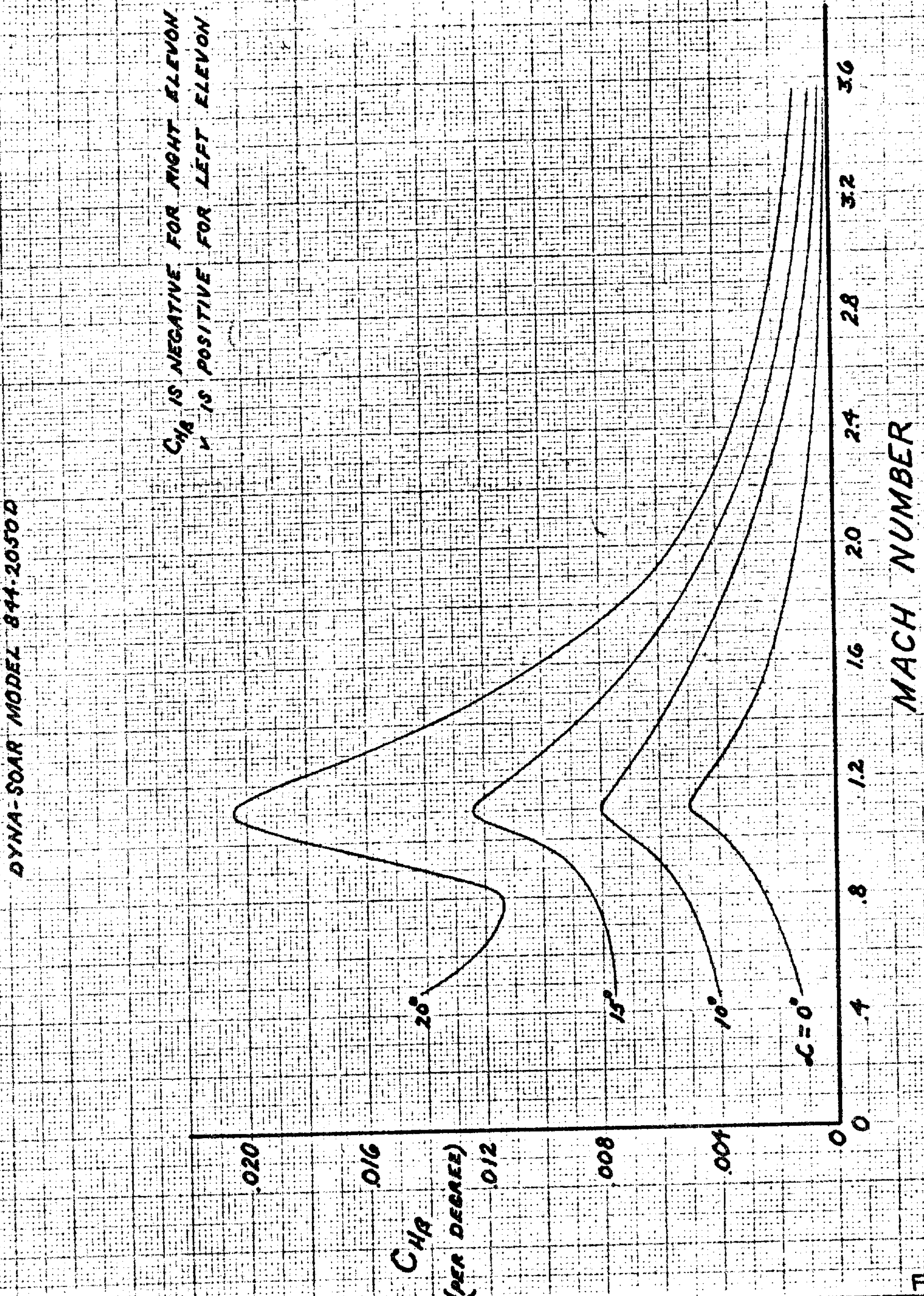

FIG. 6.68

CALC	[signature]	12-7-61	REVISED	DATE	EFFECT OF MACH NUMBER ON ELEVON HINGE MOMENT DERIVATIVE C_{h_δ}	844-2050D
CHECK			12-20-61			D2-80065
APR					BOEING AIRPLANE COMPANY	PAGE 6.78
APR						

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K2 ALBANENE 195L TRACING PAPER 60629

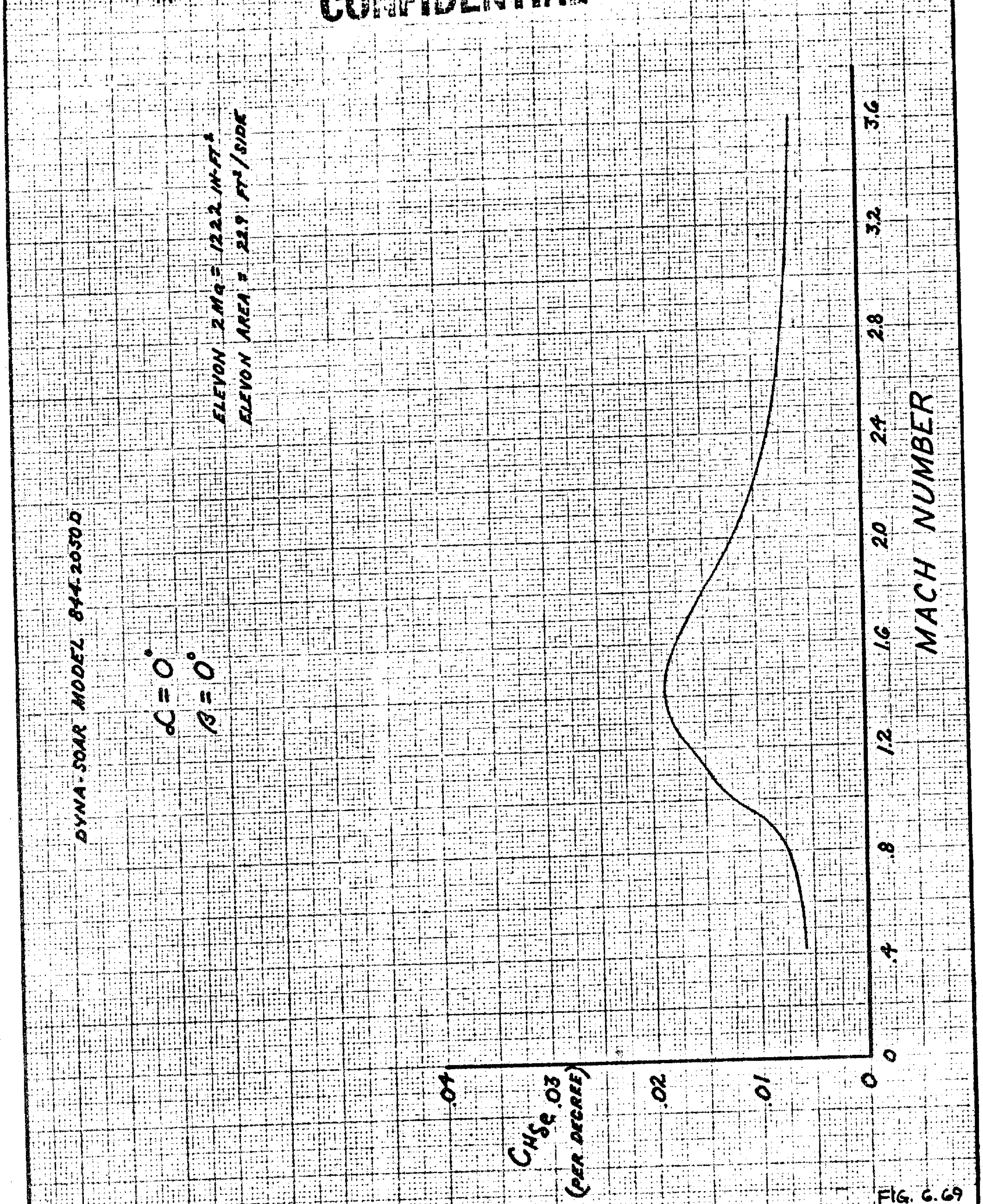

FIG. 6.69

CALC	A.C.	12-7-61	REVISED	DATE	EFFECT OF MACH NUMBER ON ELEVON HINGE MOMENT DERIVATIVE $C_{H_{\delta e}}$	844-2050D
CHECK			12-20-1			D2-80065
APR					BOEING AIRPLANE COMPANY	PAGE 6.79
APR						

U3 4013 8000 (WAS BAC 461 C-R4)

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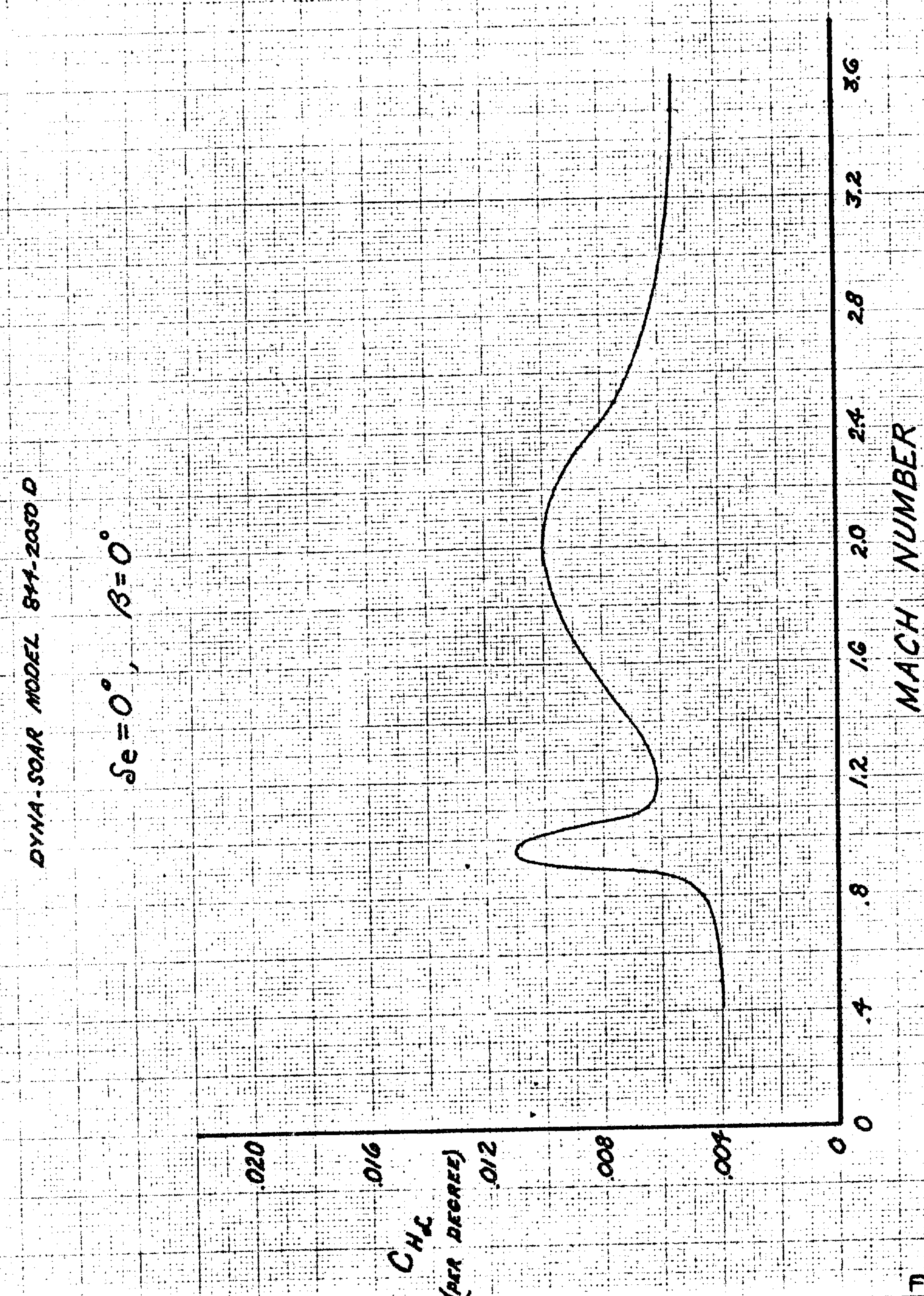

FIG. 6.70

			REVISED	DATE		
CALC	Ward D.C.	12-7-61	12-20-1		EFFECT OF MACH NUMBER ON ELEVON HINGE MOMENT DERIVATIVE $C_{H_{\mathcal{L}}}$	844-2050 D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.80
APR						

US 4013 8000

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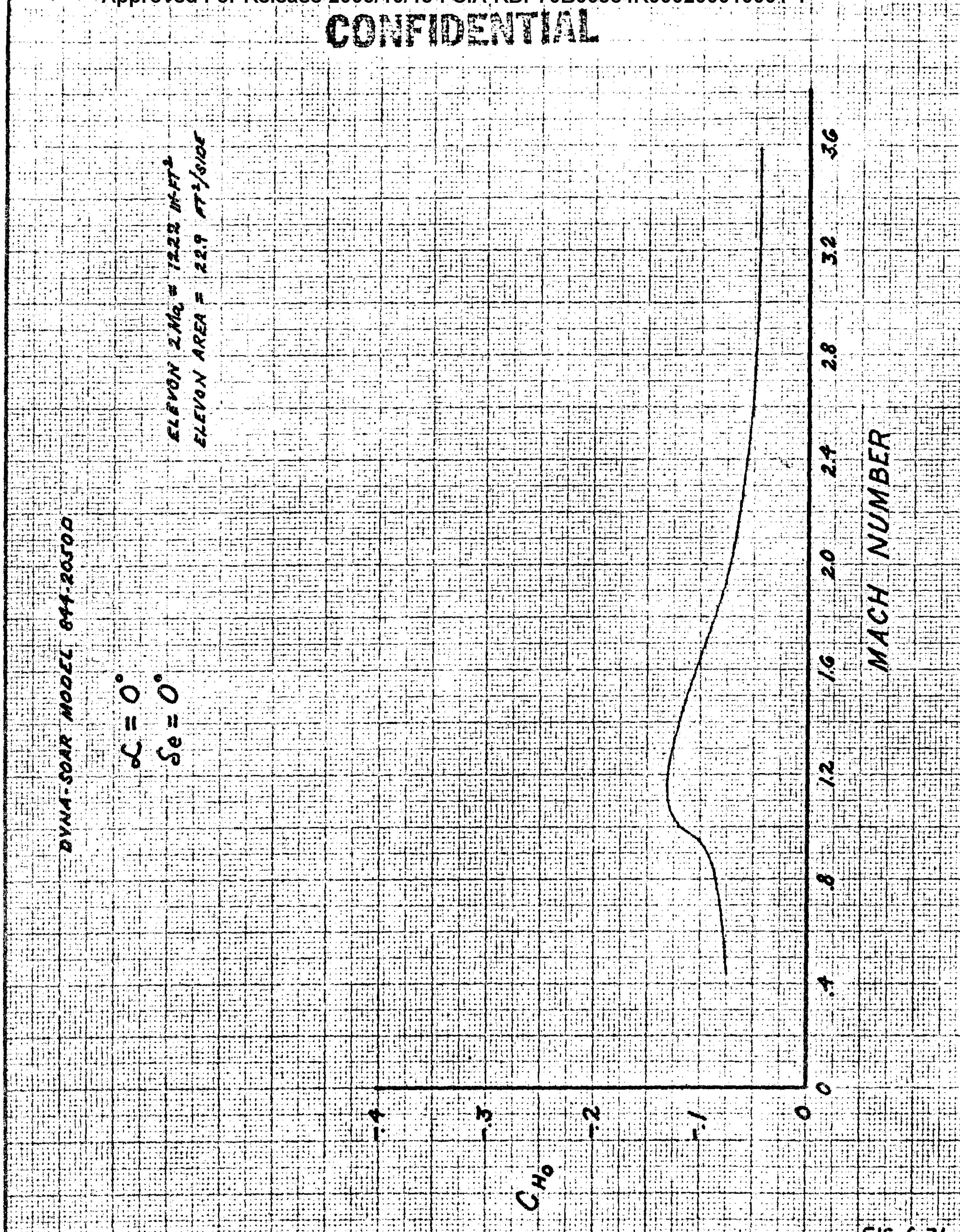

FIG. 6.71

CALC	Hood, A.S.	12-7-61	REVISED	DATE
CHECK			12-20-1	
APR				
APR				

EFFECT OF MACH NUMBER ON ELEVON HINGE MOMENT COEFFICIENT

$\alpha = 0°$, $\delta_e = 0°$

BOEING AIRPLANE COMPANY

844-2050D

D2-80065

PAGE 6.81

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K-E ALBANENE 196L TRACING PAPER 60629

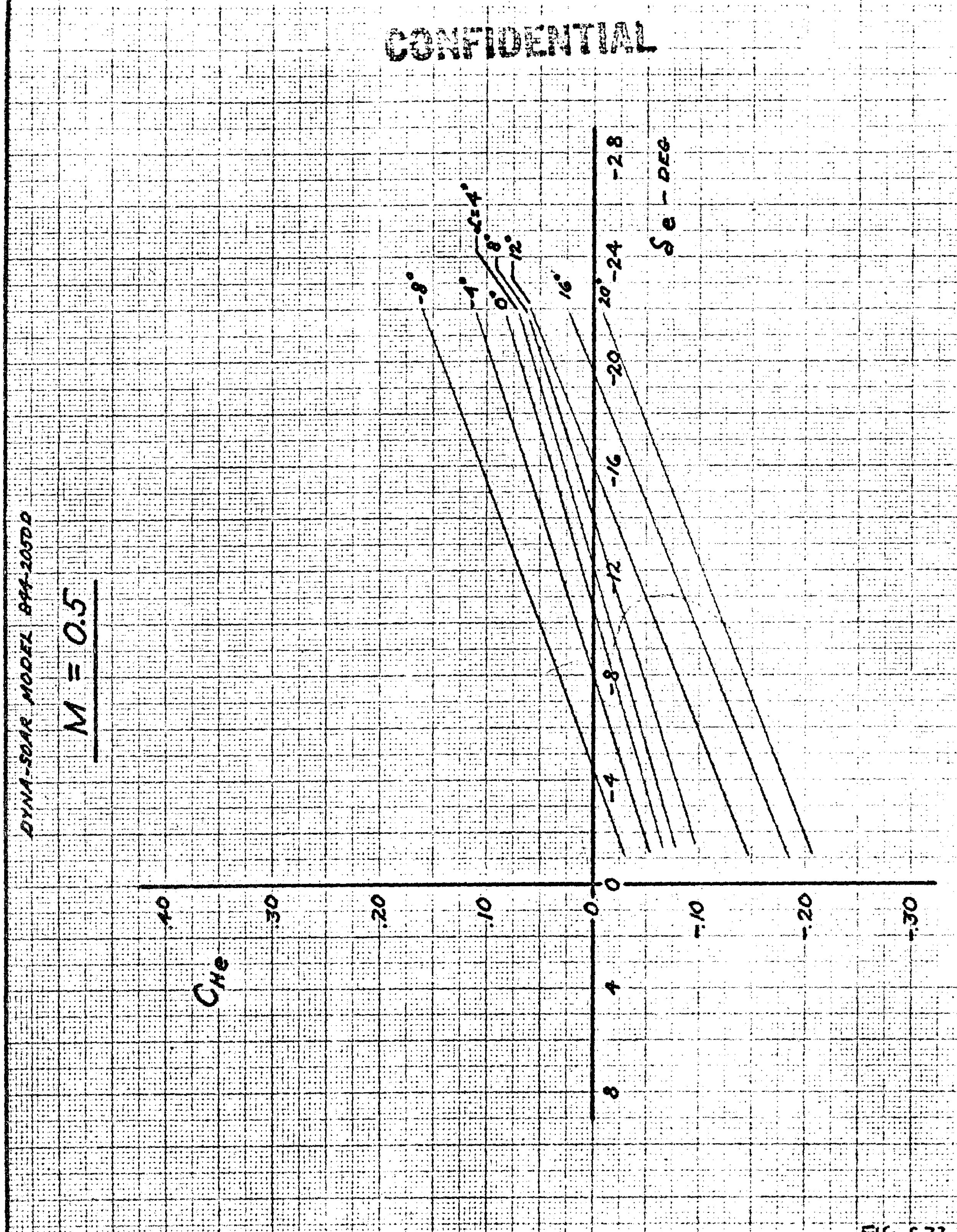

FIG. 6.72

CALC	[illegible]	11-6-61	REVISED	DATE	EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 0.50
CHECK			12-[illegible]		
APR					
APR					THE BOEING COMPANY

844-2050D

D2-80065

PAGE 6.82

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K-E ALBANENE 195L TRACING PAPER 60629

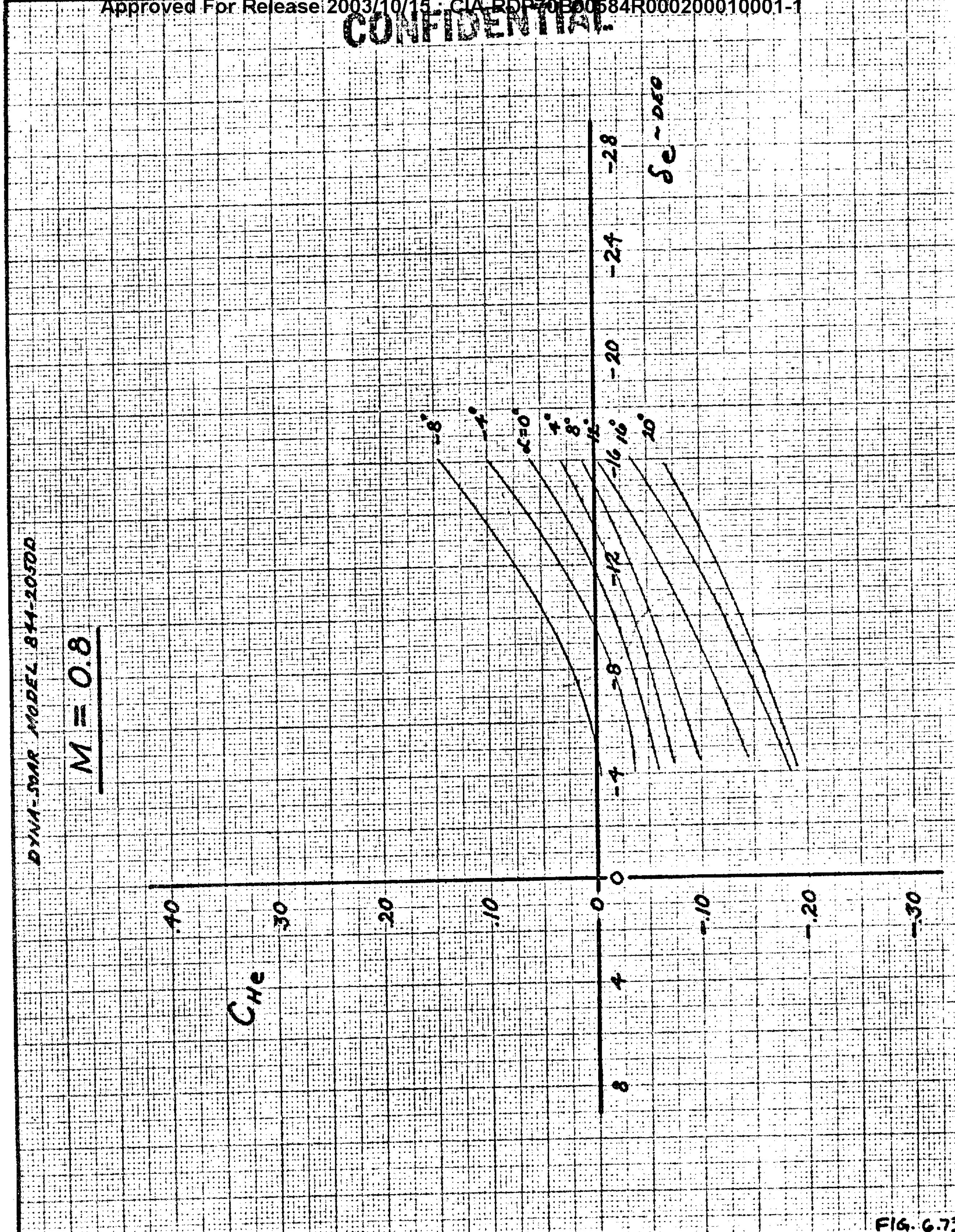

FIG. 6.73

CALC	[illegible]	11-6-61	REVISED	DATE	EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 0.80	844-2050D
CHECK			12-20-1			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.83

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W, B, E, V 2050D

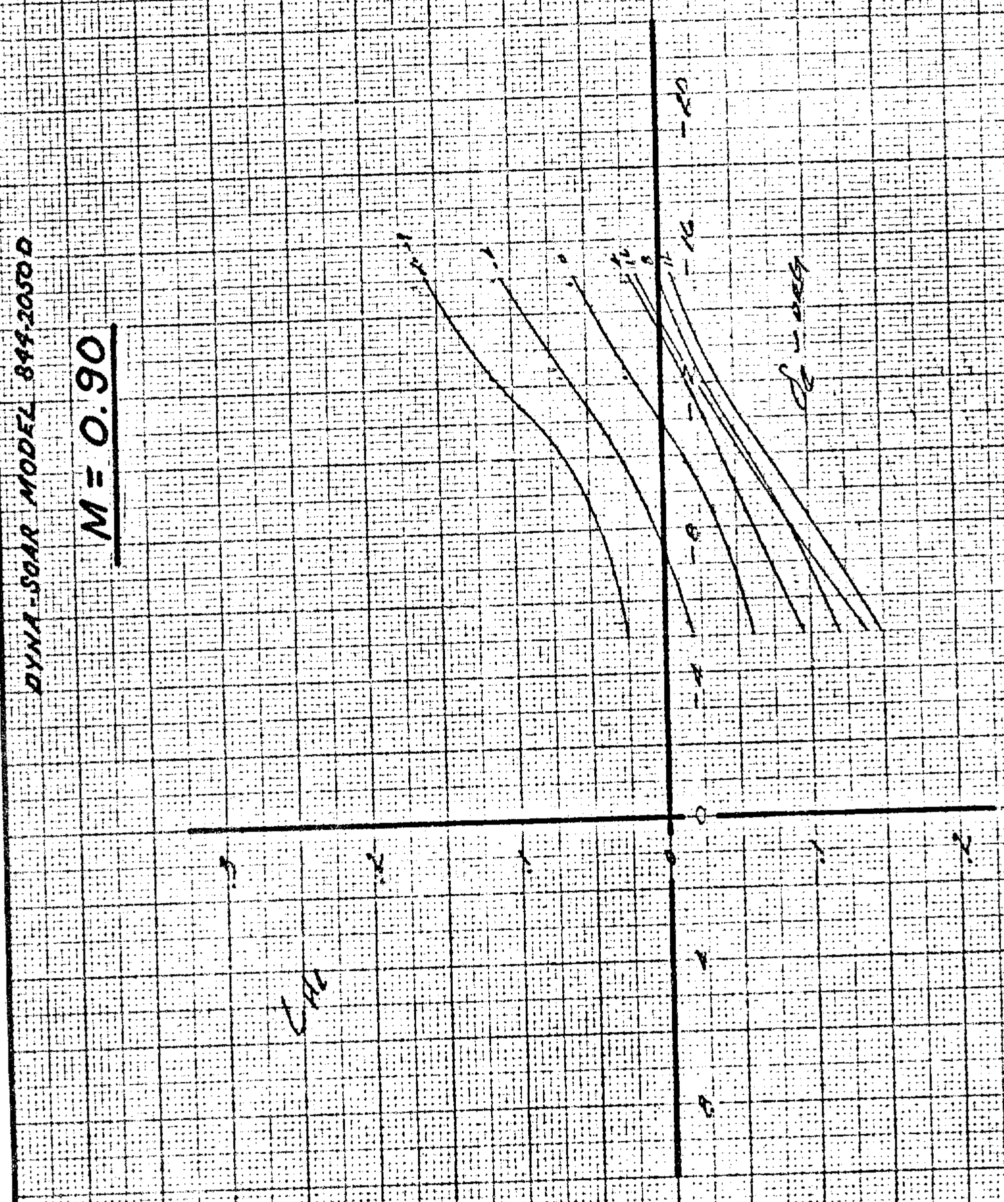

FIG. 6.74

CALC			REVISED	DATE	EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 0.90	844-2050D
CHECK			12-2-61			D2-80065
APR						PAGE 6.84
APR					THE BOEING COMPANY	

U3 4013 8000

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DYNA-SOAR MODEL 844-2050D

M=0.95

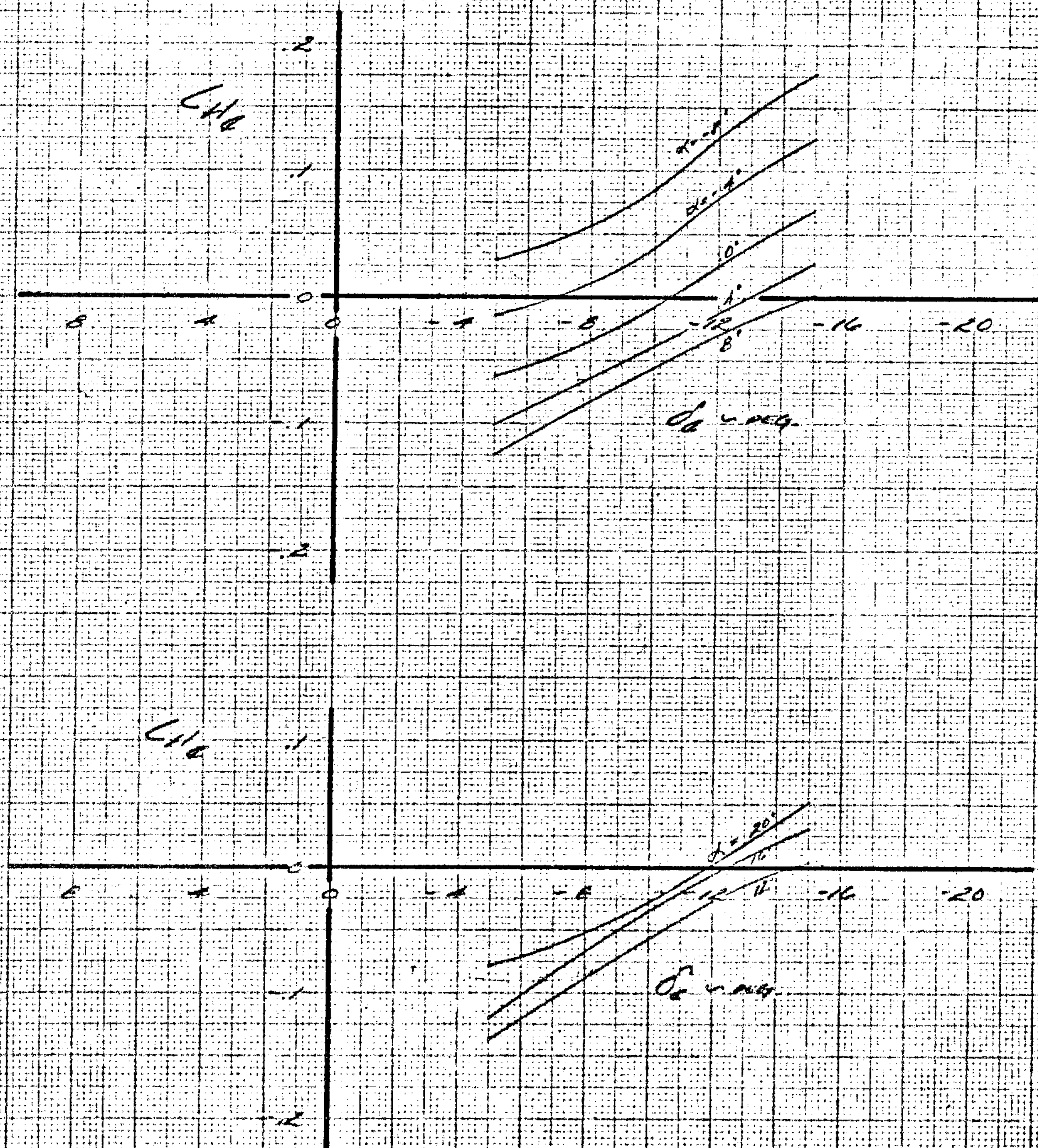

FIG. 6.75

CALC			REVISED	DATE
CHECK			12-20-1	
APR				
APR				

EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 0.95

844-2050D

D2-80065

THE BOEING COMPANY

PAGE 6.85

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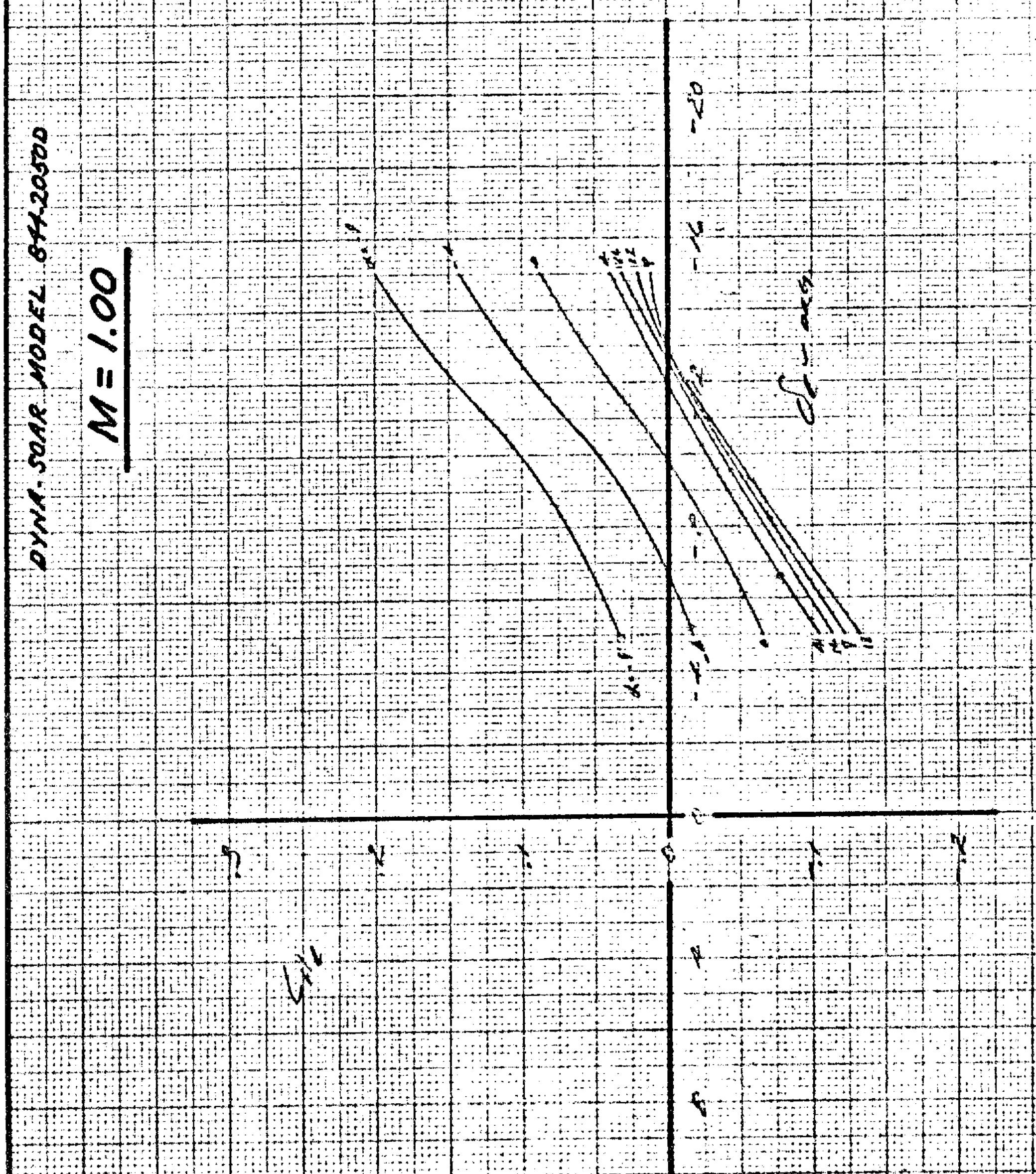

FIG. 6.76

CALC			REVISED	DATE	EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 1.00	844-2050D
CHECK			12-2			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.86

U3 4013 8000

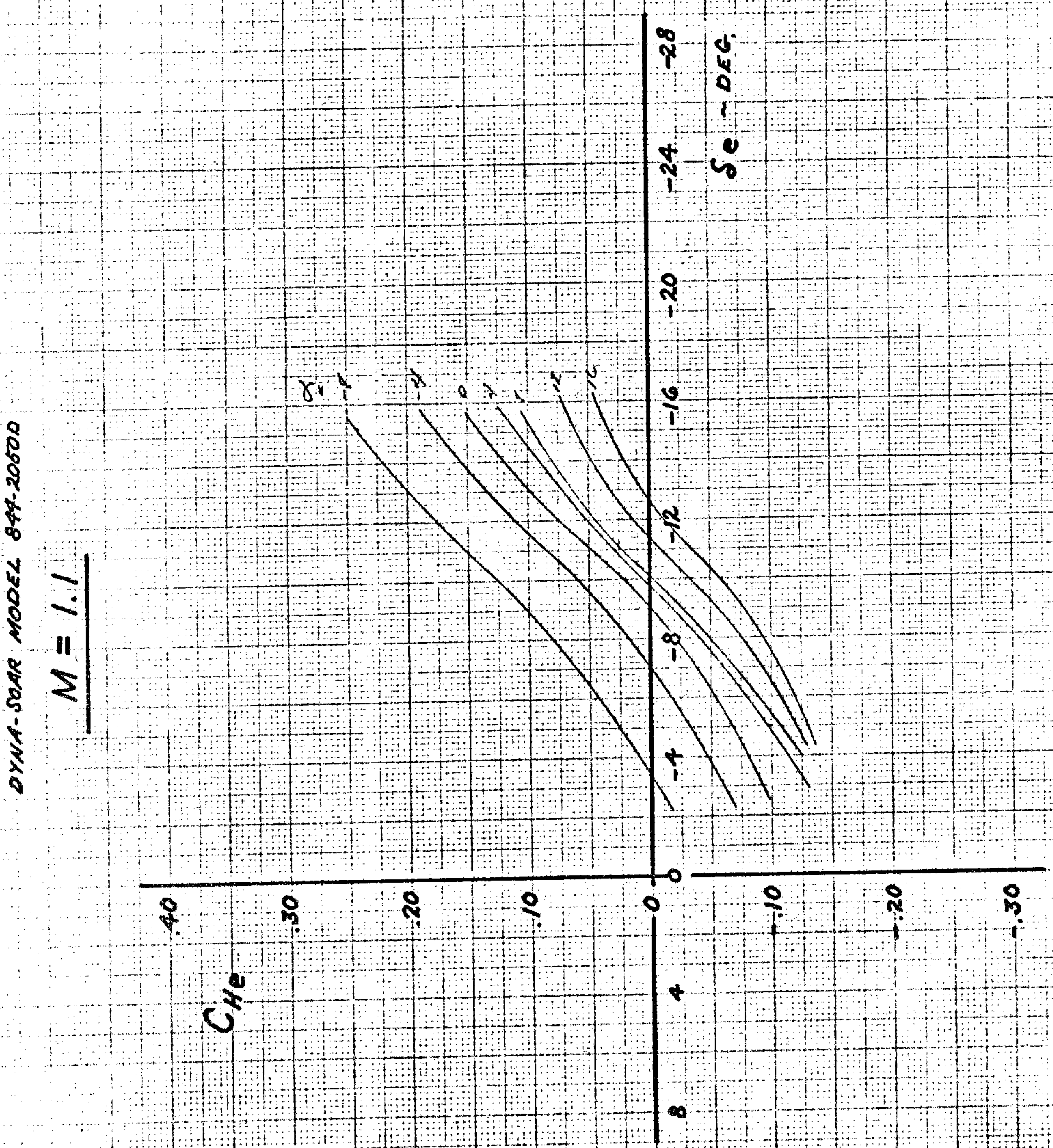

FIG. 6.77

			REVISED	DATE		
CALC	Hood A.E.	11-3-61	12-20-1		EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 1.10	844-2050D
CHECK						D2-80065
APR					THE BOEING COMPANY	PAGE 6.87
APR						

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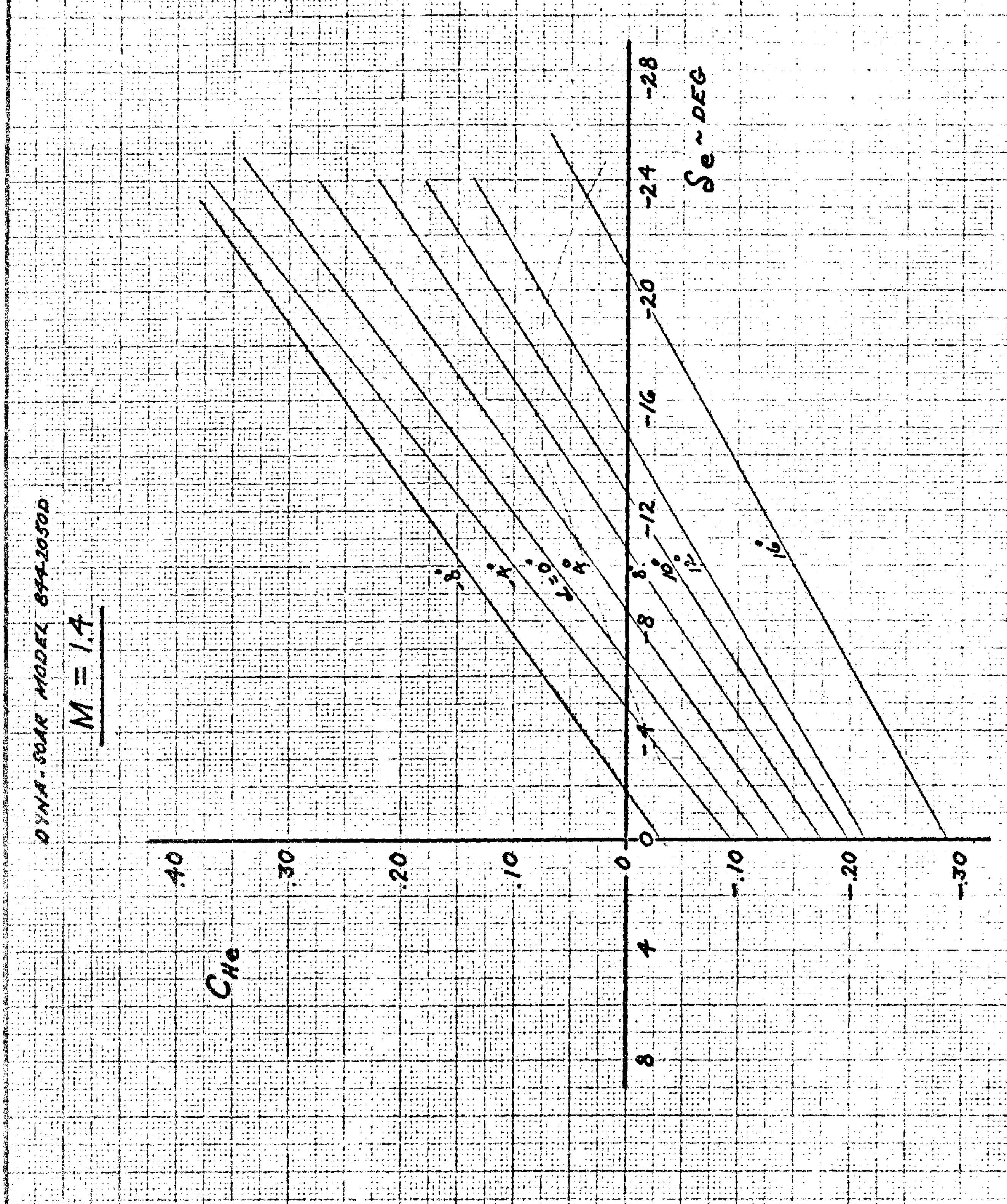

FIG. 6.78

CALC	Wood A.C.	11-3-61	REVISED	DATE	EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 1.40	844-2050D
CHECK			12-20-61			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.88

U3 4013 8000

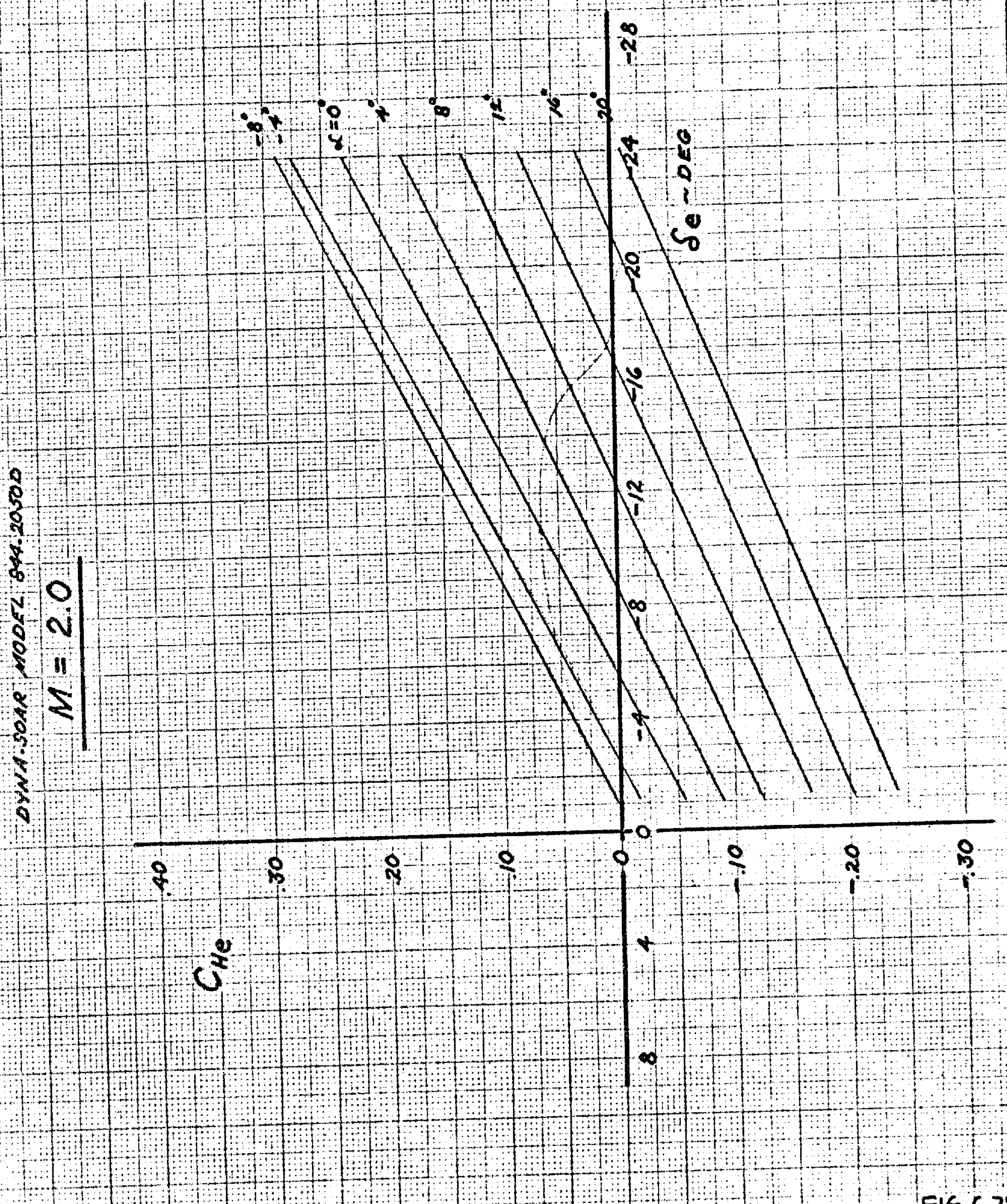

FIG. 6.79

CALC	Wood G.E.	11-6-61	REVISED	DATE	EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 2.00	844-2050D
CHECK			12-20-1			D2-80065
APR						PAGE 6.89
APR					THE BOEING COMPANY	

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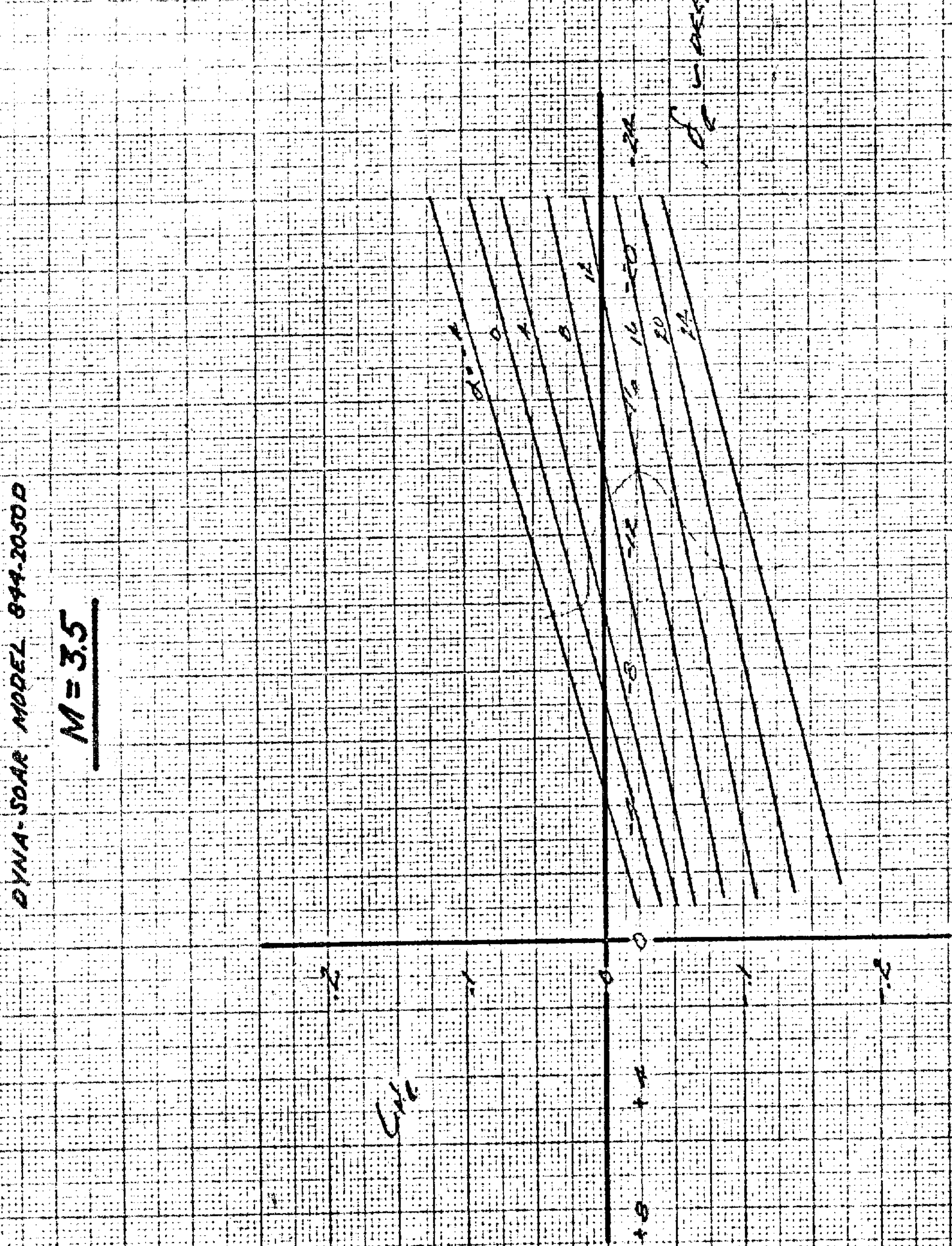

FIG. 6.80

			REVISED	DATE		
CALC	[illegible]	4-6-1	12-2?-1		EFFECT OF ELEVON DEFLECTION ON HINGE MOMENT M = 3.50	844-2050D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.90

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U3 4013 800

ALBANENE 196L TRACING PAPER 60629

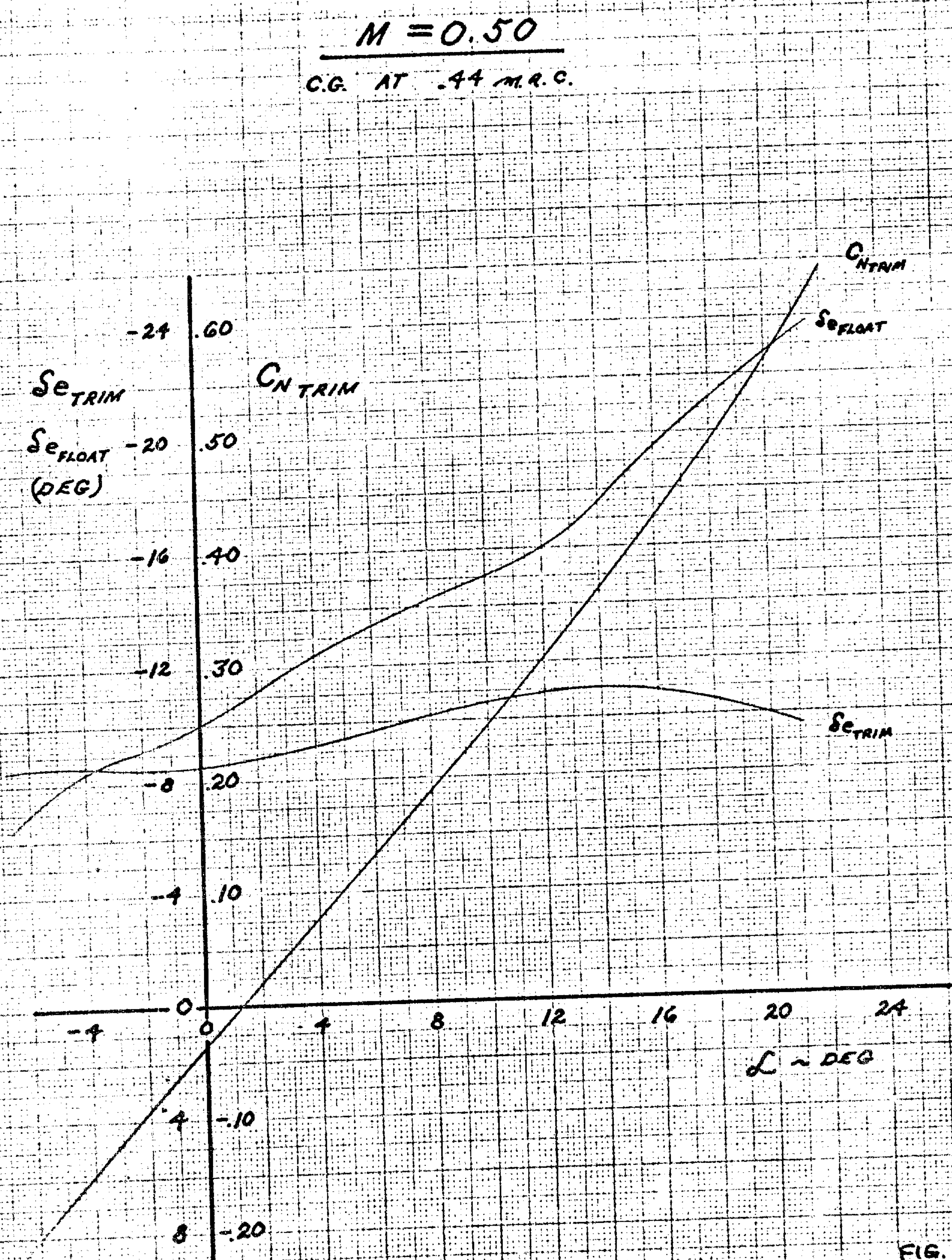

FIG. 6.81

CALC	[signature]	11-13-61	REVISED	DATE	ELEVON FLOAT & TRIM COMPARSION GLIDER ALONE M = 0.50
CHECK			12-20-1		
APR					THE BOEING COMPANY
APR					

844-2050D

D2-80065

PAGE 6.91

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U3 4013 8000

DYNA-SOAR MODEL 844-2050D

M = 0.80

C.G. = .44 mac

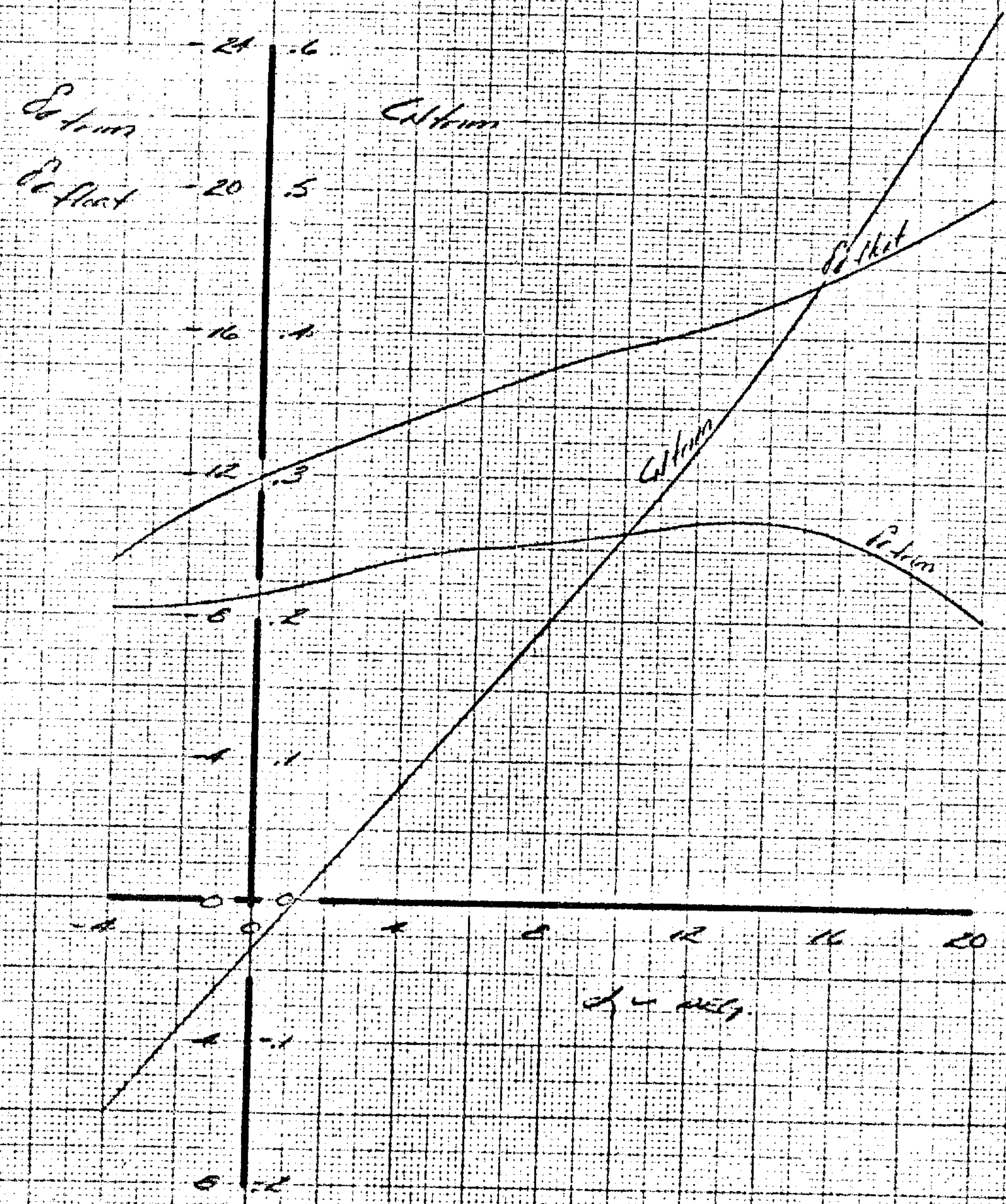

FIG. 6.82

CALC	Swain	11-12-?	REVISED	DATE	ELEVON FLOAT & TRIM COMPARSION GLIDER ALONE M = 0.80	844-2050D
CHECK			12-?-?			D2-80065
APR					THE BOEING COMPANY	PAGE 6.92
APR						

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U3 4013 8000 K+E ALBANENE TRACING PAPER 60629

M = 0.95

C.G. AT .44 m.a.c.

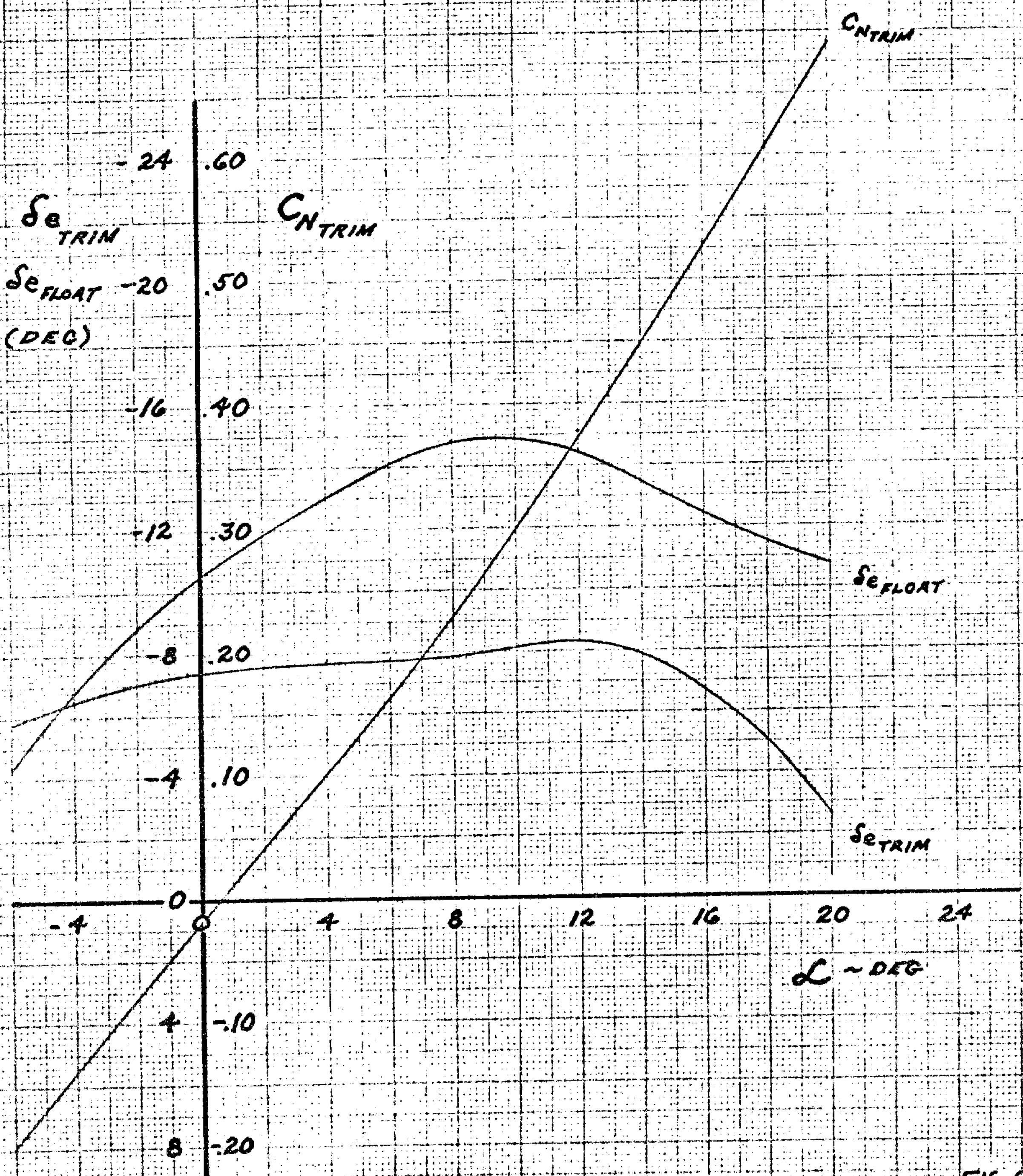

FIG. 6.93

CALC	Wood A.E.	11-14-61	REVISED	DATE	ELEVON FLOAT & TRIM COMPARSION GLIDER ALONE M = 0.95	844-2050D
CHECK			12-...			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.93

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U3 4013 8000

DYNA-SOAR MODEL 844-2050D

M = 1.00

C.G. = .44 mac

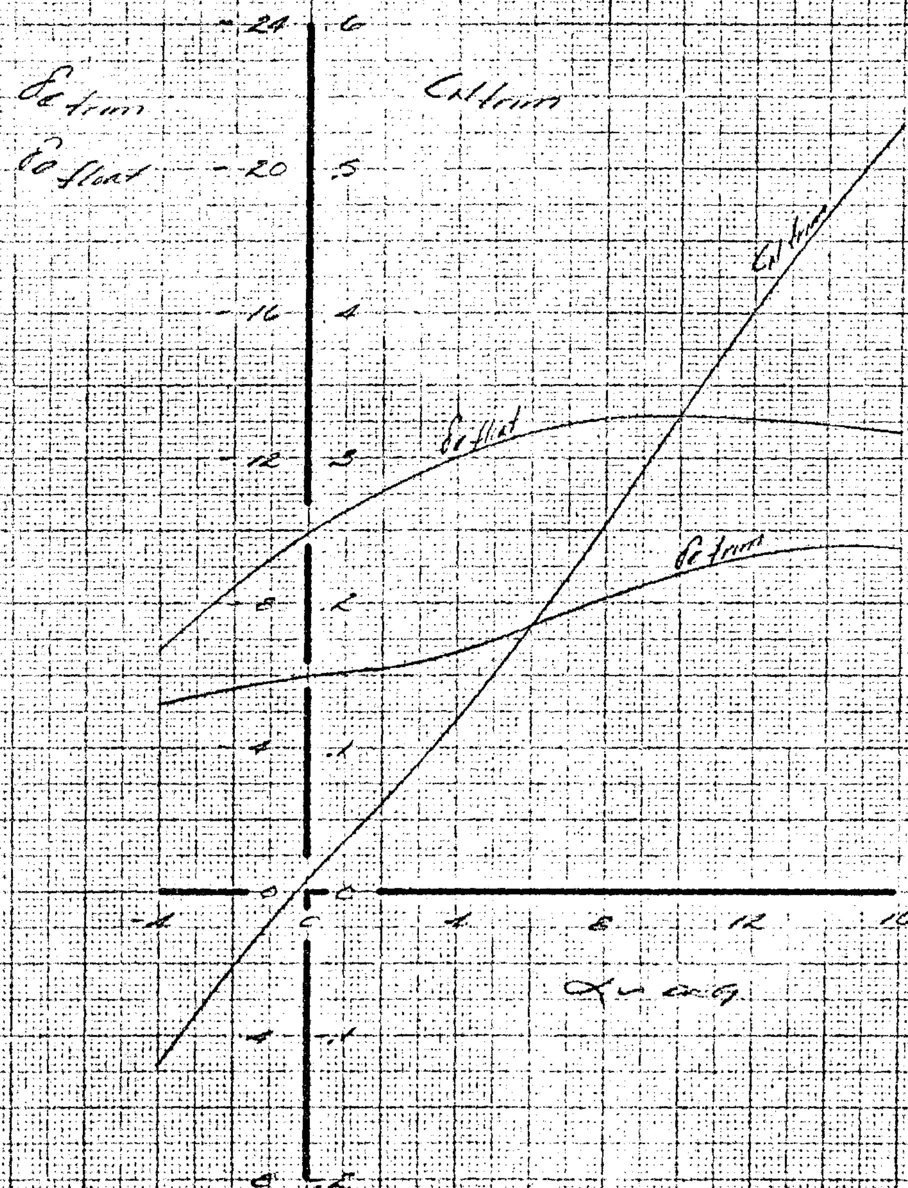

FIG. 6.84

CALC			REVISED	DATE	ELEVON FLOAT & TRIM COMPARSION GLIDER ALONE M = 1.00	844-2050D
CHECK			12-20-1			D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.94

W, B, E, VP

~ 168

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844-2050 D

M = 1.10

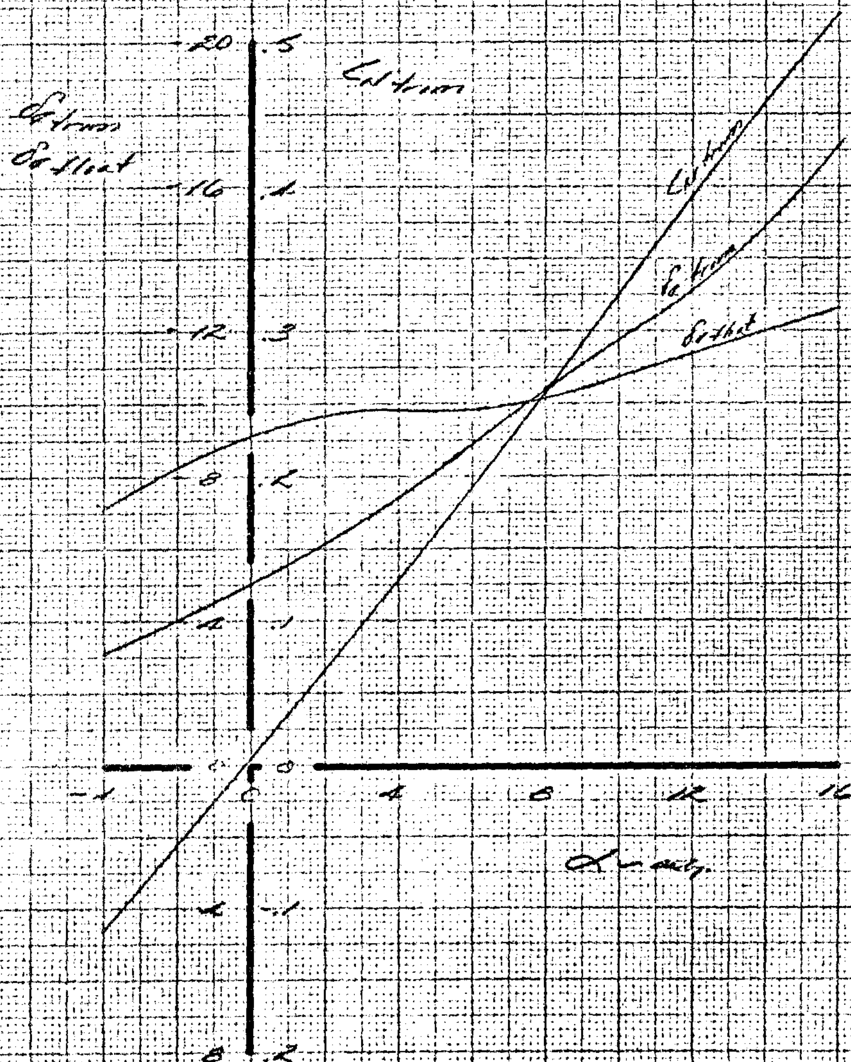

FIG. 6.85

CALC			REVISED	DATE	ELEVON FLOAT & TRIM COMPARSION GLIDER ALONE M = 1.10	844-2050D
CHECK						D2-80065
APR						
APR					THE BOEING COMPANY	PAGE 6.95

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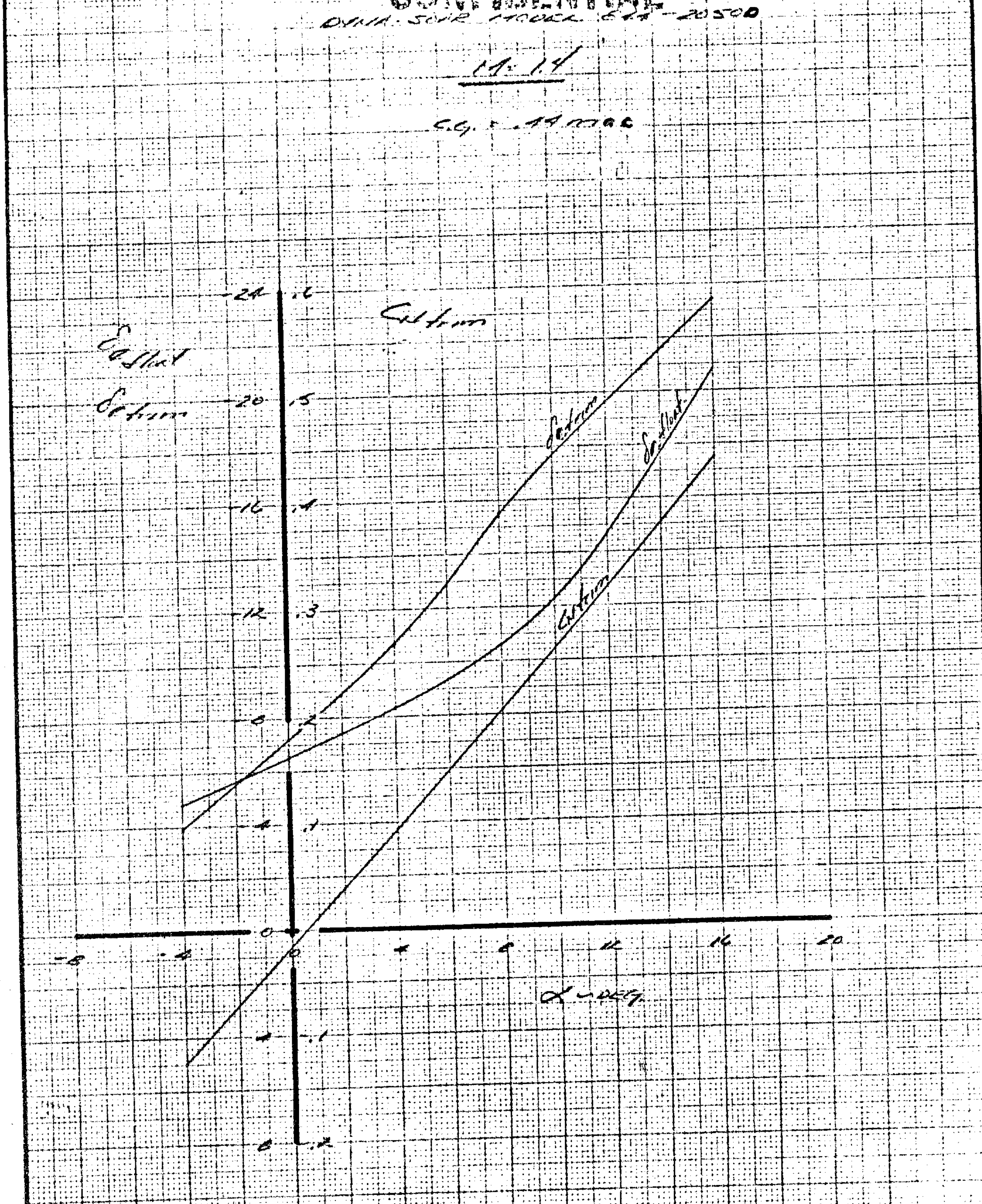

FIG. 6.86

CALC			REVISED	DATE	ELEVON FLOAT & TRIM COMPARSION GLIDER ALONE M = 1.40	844-2050D
CHECK			12-...			D2-80065
APR						PAGE
APR					THE BOEING COMPANY	6.96

U3 4013 8000

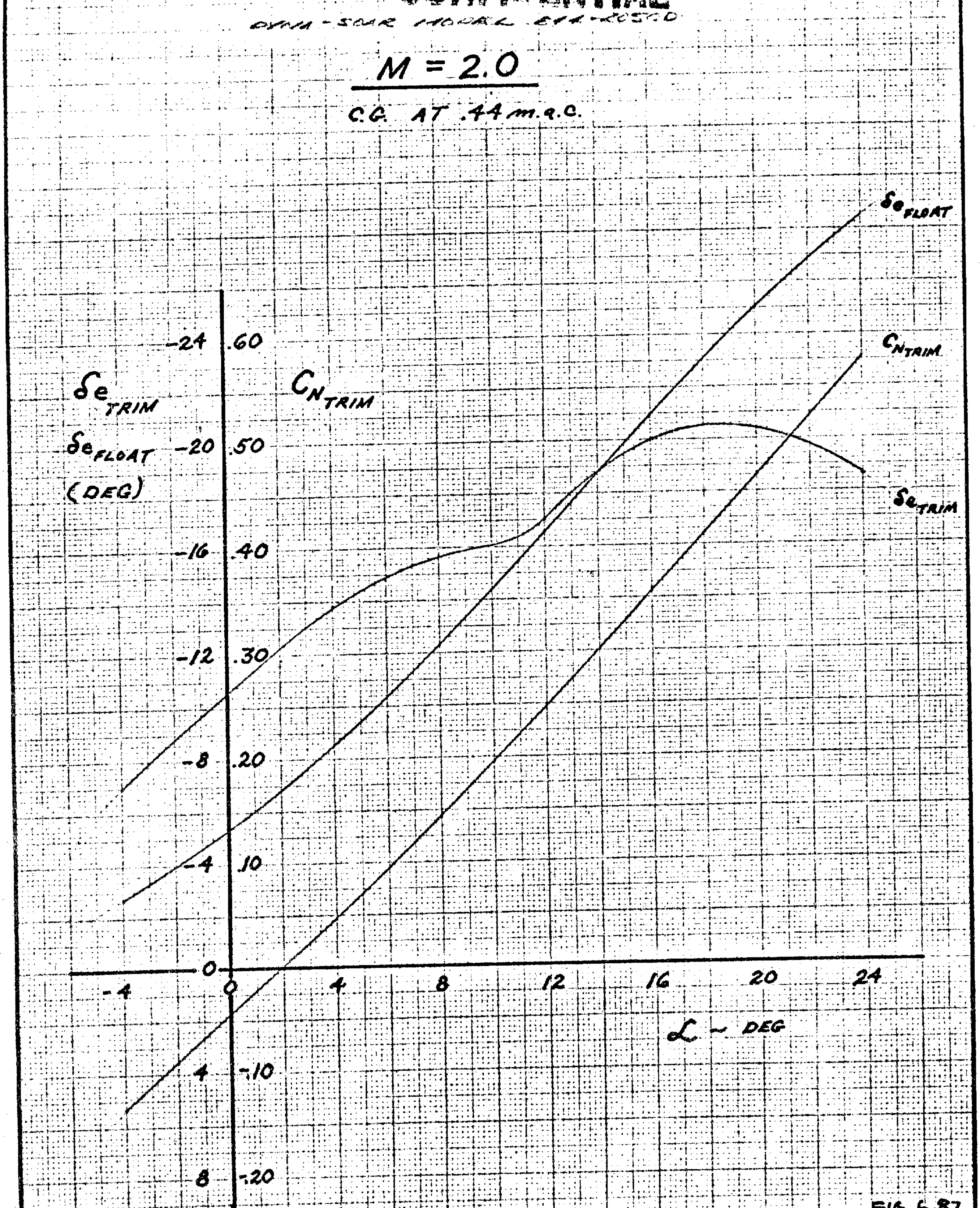

FIG. 6.87

CALC	W.A.E.	11-11-61	REVISED	DATE
CHECK				
APR				
APR				

ELEVON FLOAT & TRIM COMPARSION
GLIDER ALONE
M = 2.00

THE BOEING COMPANY

844-2050D

D2-80065

PAGE 6.97

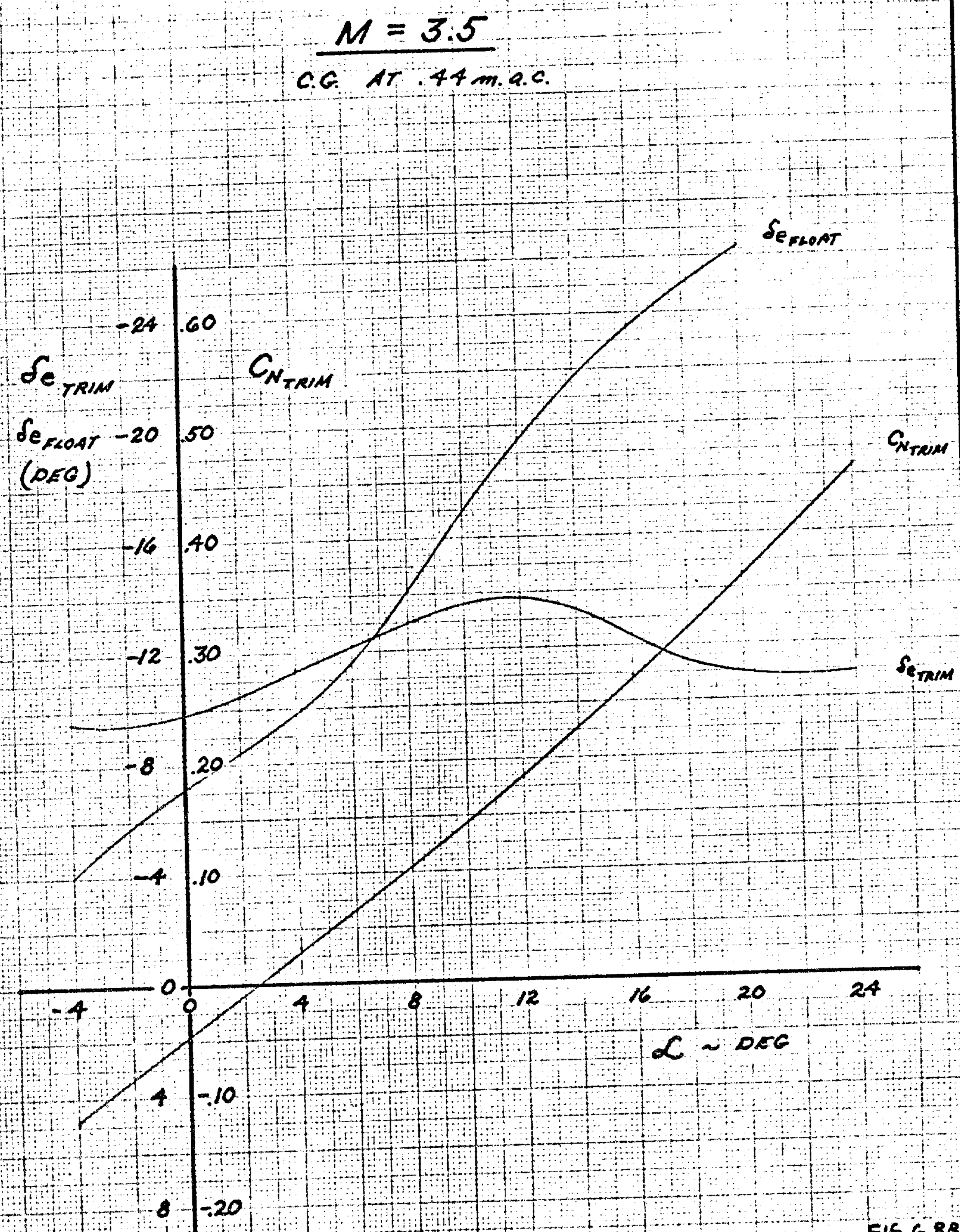

FIG. 6.88

CALC.	Hoof A.E.	11-9-61	REVISED	DATE	ELEVON FLOAT & TRIM COMPARSION GLIDER ALONE M = 3.50	844-2050D
CHECK			12-2?-1			D2-80065
APR						PAGE
APR					THE BOEING COMPANY	6.98

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U3 4013 8000

6.2 LATERAL-DIRECTIONAL STABILITY AND CONTROL

Lateral-directional stability and control characteristics for model 844-2050 D glider configuration are presented in Figures 6.89 through 6.97. All data shown are for a rigid glider with the c.g. at .44$\bar{c}$ and waterline 124. Aeroelastic effects are given in section 8. Figures are shown with the elevons in longitudinal trim position, except for the aileron characteristics where symmetric deflections from the trim position have been considered. Summary Mach number curves of directional aerodynamic center, directional stability, lateral stability and side force derivative are shown in Figures 6.89-6.92. Lateral-directional control characteristics, yawing and rolling moment variation with rudder or aileron deflection, are shown in Figures 6.93 through 6.97. At individual Mach numbers, lateral-directional characteristics have been presented versus sideslip angle to show existing non-linearities. More detail of the incremental effects of rudder or aileron deflections has also been shown at constant Mach numbers. Rudders are deflected about a 6 degree trail position below a Mach number of 2.5 and about a position faired with the vertical at higher Mach numbers. Both rudders are deflected simultaneously between limits of 12 degrees inboard and 35 degrees outboard.

Curves are based on wind tunnel data and analytical estimates. Subsonic and transonic data were obtained in the Boeing Transonic Wind Tunnel, while supersonic data came from tests in the Boeing Supersonic Wind Tunnel. Jet Propulsion Laboratory 21" Hypersonic Wind Tunnel and Arnold Center Tunnel B provided the hypersonic data. Consideration was also given to previous high Mach number data from Boeing Hot Shot Wind Tunnel on a similar glider configuration.

12-20-1

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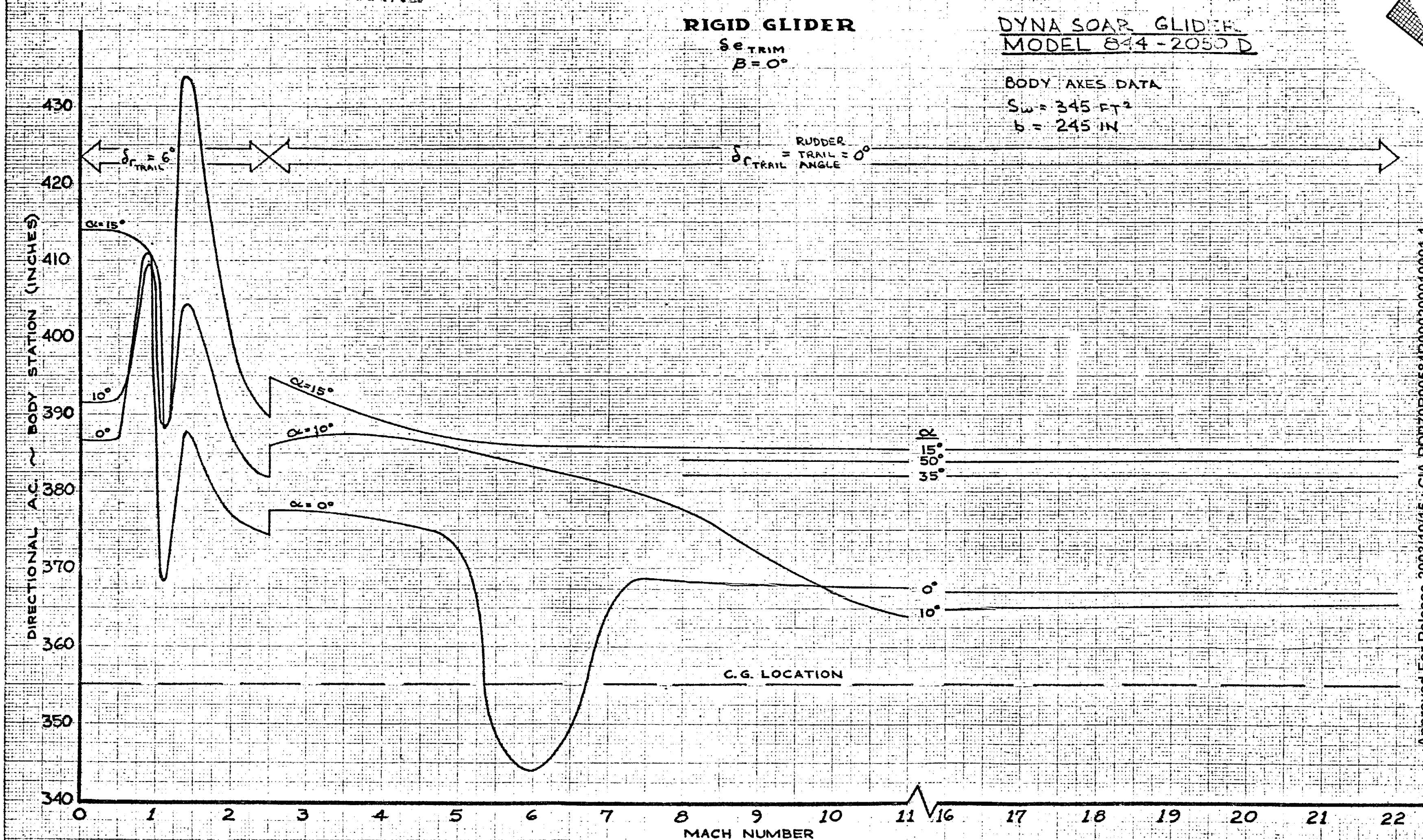

CALC	FTV/GDK	12-12-61	REVISED	DATE
CHECK			12-20-61	
APPD				
APPD				

FIG. 6.89

DIRECTIONAL AERODYNAMIC CENTER

844-2050 D

D2-80065

PAGE 6-100

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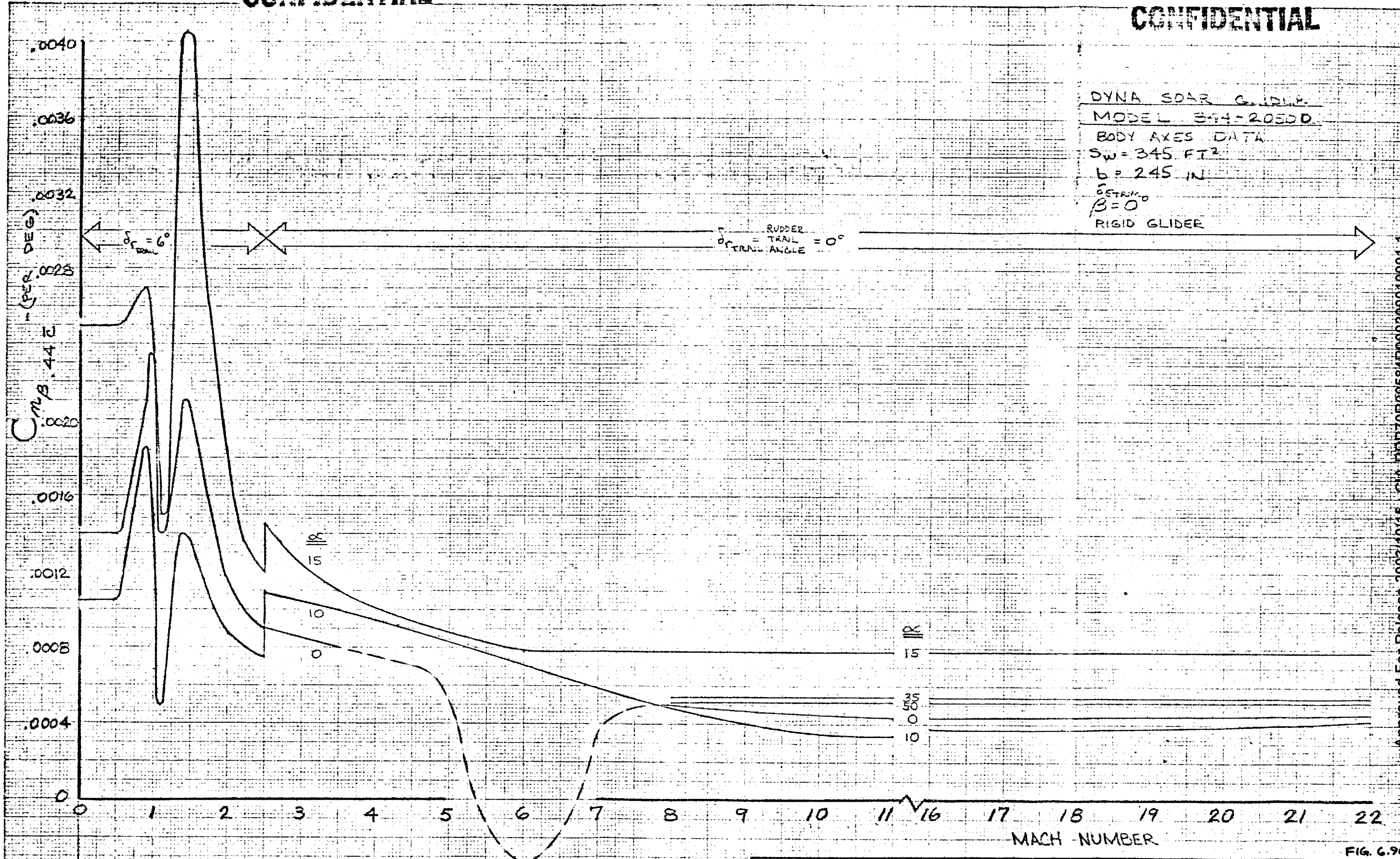

CALC	PTV-...		REVISED	DATE	DIRECTIONAL STABILITY	FIG. 6.90
CHECK						844-2050D
APPD						D2-80065
APPD						PAGE 6.101

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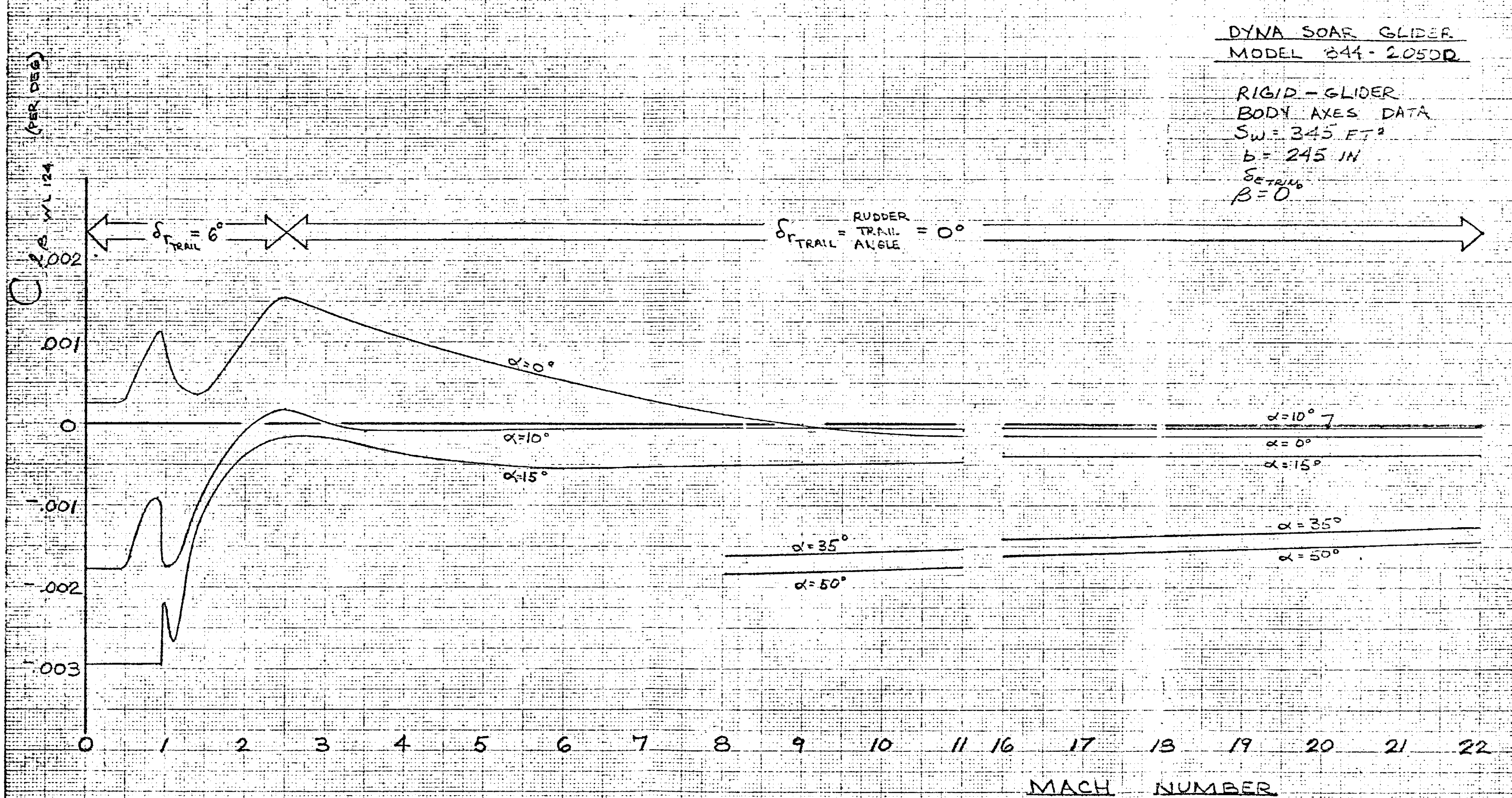

FIG. 6.91

CALC	PTV	11/17/1	REVISED	DATE	LATERAL STABILITY	844-2050D
CHECK			12-20-1			D2-80065
APPD						
APPD						PAGE 6.102

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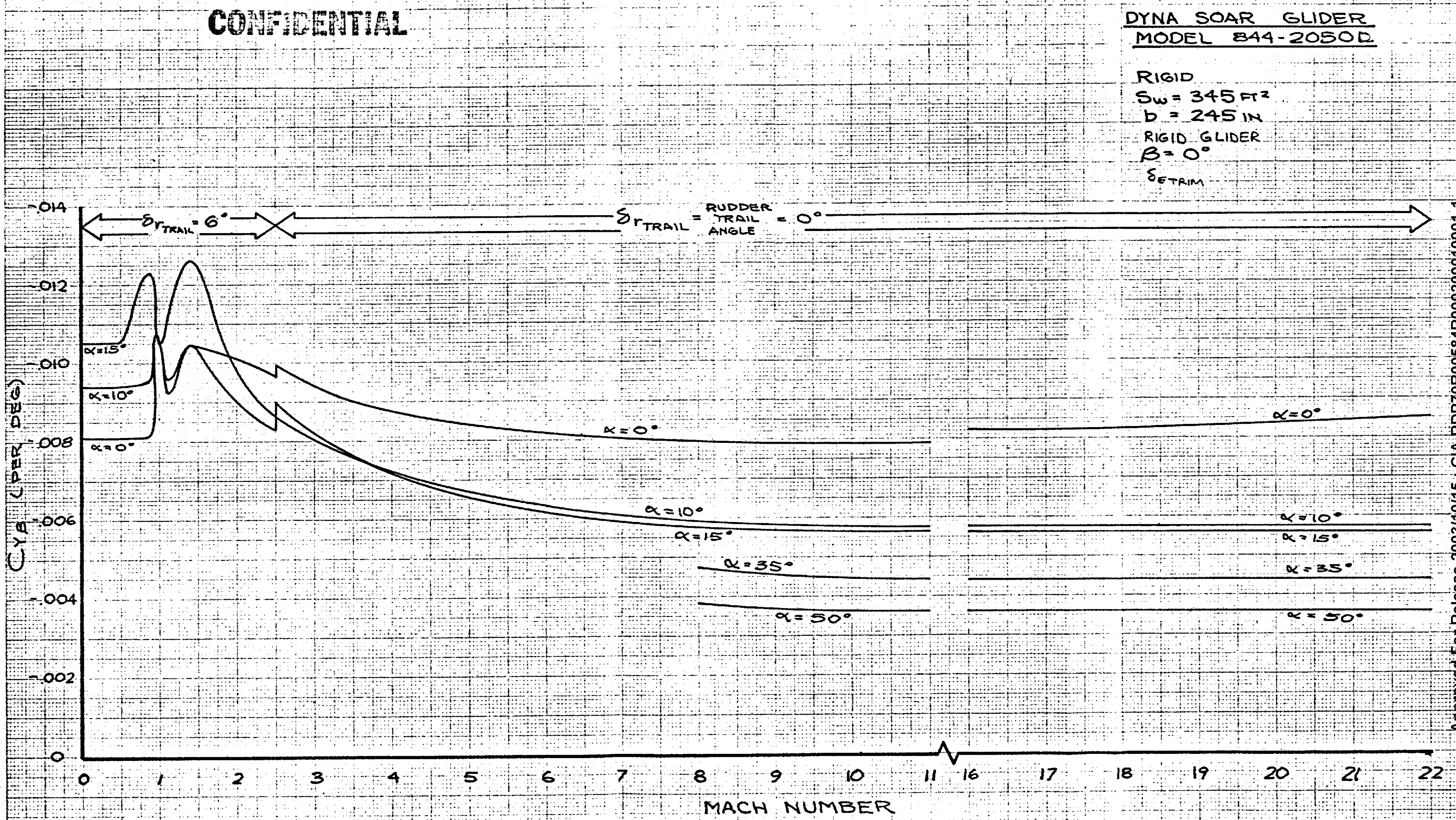

CALC	PTV	11/21/1	REVISED	DATE	SIDE FORCE DERIVATIVE	FIG. 6.92
CHECK			12-2-1			844-2050D
APPD						D2-80065
APPD						PAGE 6-103
DRN	R.RICE	11-21-1				

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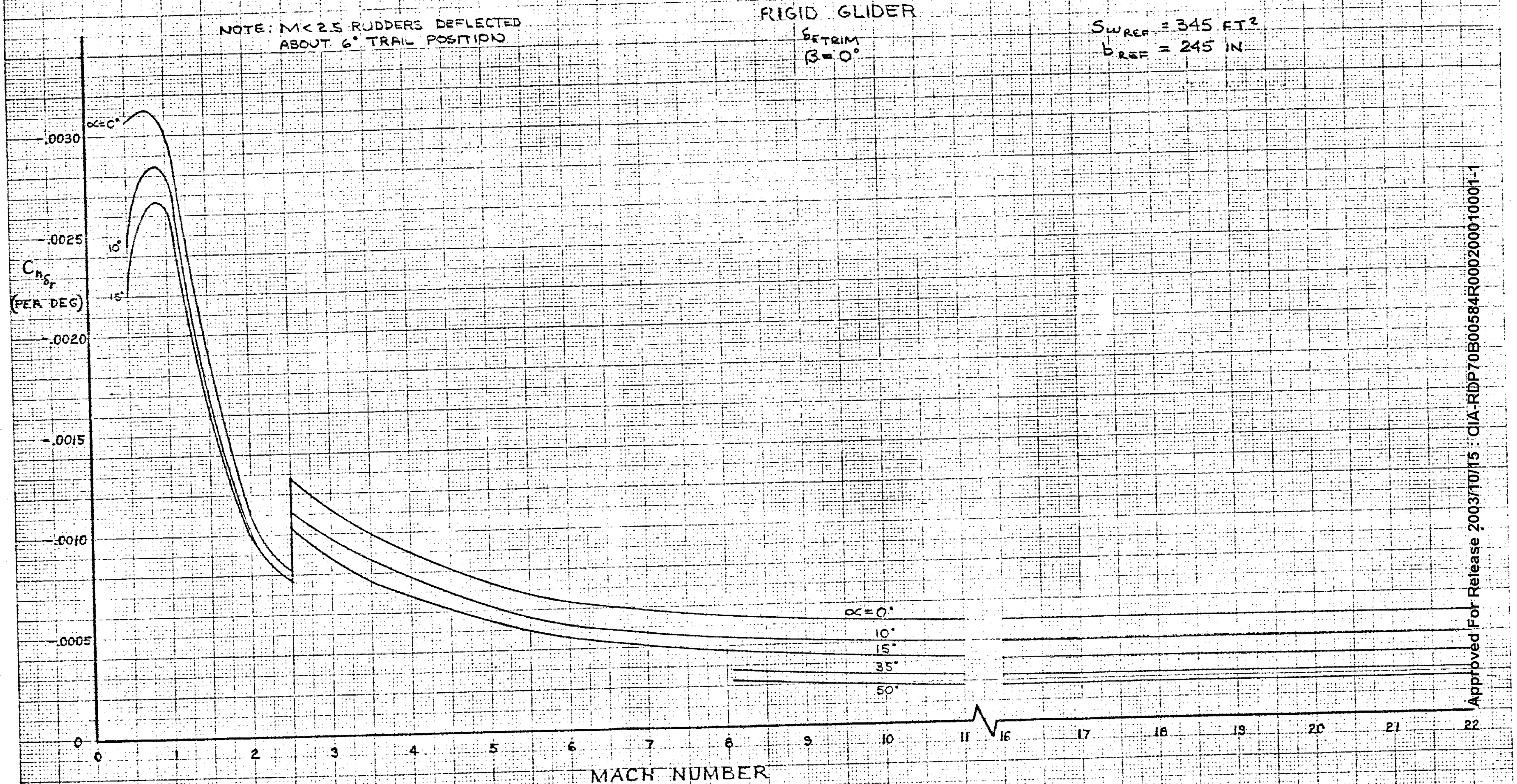
DYNA SOAR GLIDER
MODEL 844-2050D

$S_{W_{REF}}$ = 345 FT²
b_{REF} = 245 IN.



CALC	P.T.V./EMP		REVISED	DATE	RUDDER EFFECTIVENESS ~ YAWING MOMENT
CHECK					
APPD					
APPD					

FIG. 6.93

844-2050 D

D2-80065

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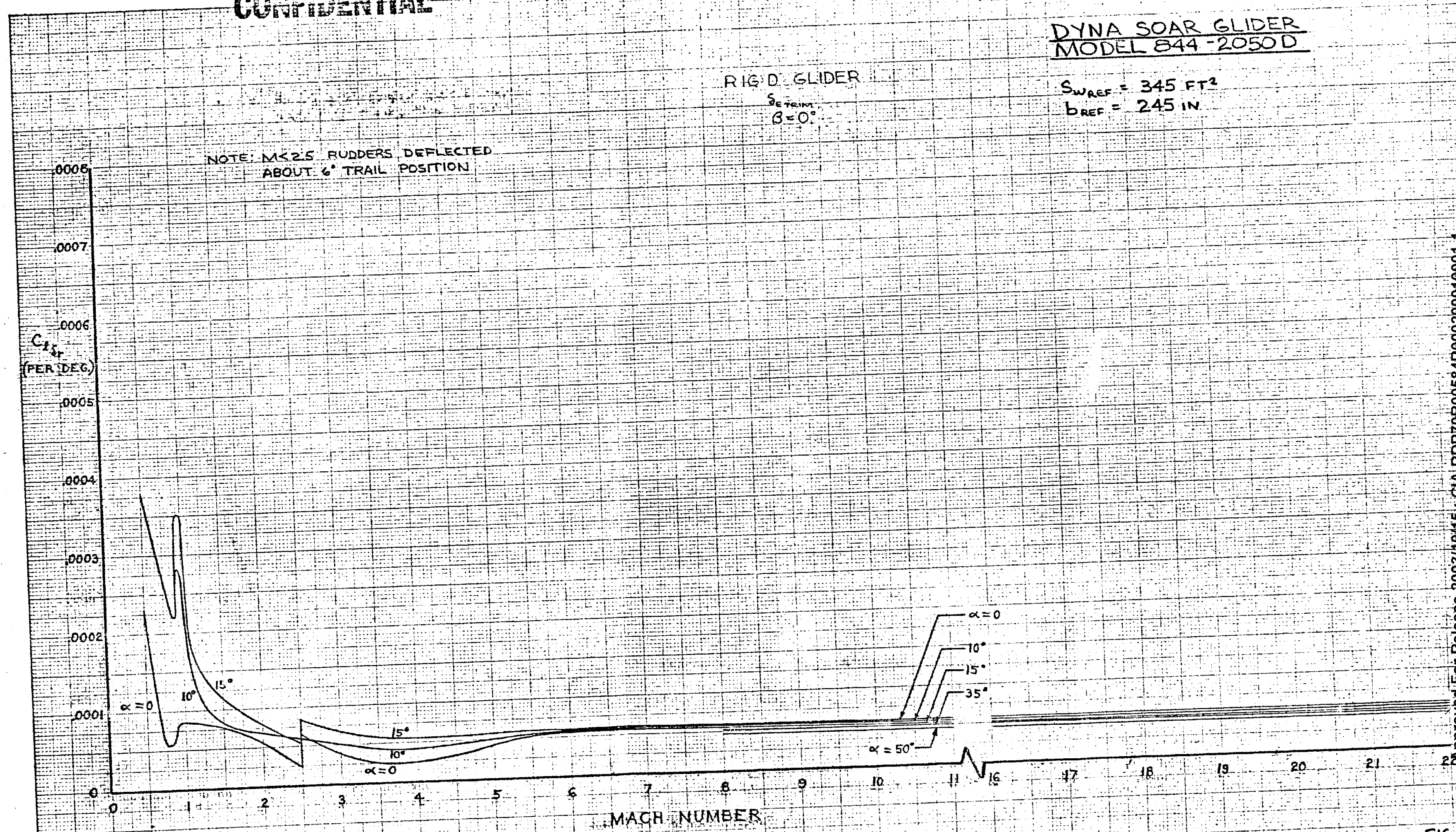

CALC	P.T.V./E.M.P.		REVISED	DATE	RUDDER EFFECTIVENESS ~ ROLLING MOMENT	FIG. 6.94
CHECK						844-2050D
APPD						D2-80065
APPD						PAGE 6.105

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DYNA SOAR GLIDER
MODEL 844-2050D

$S_{W_{REF}} = 345$ FT^2
$b_{REF} = 245$ IN

RIGID GLIDER
$\delta_{E_{TRIM}}$
$\beta = 0°$

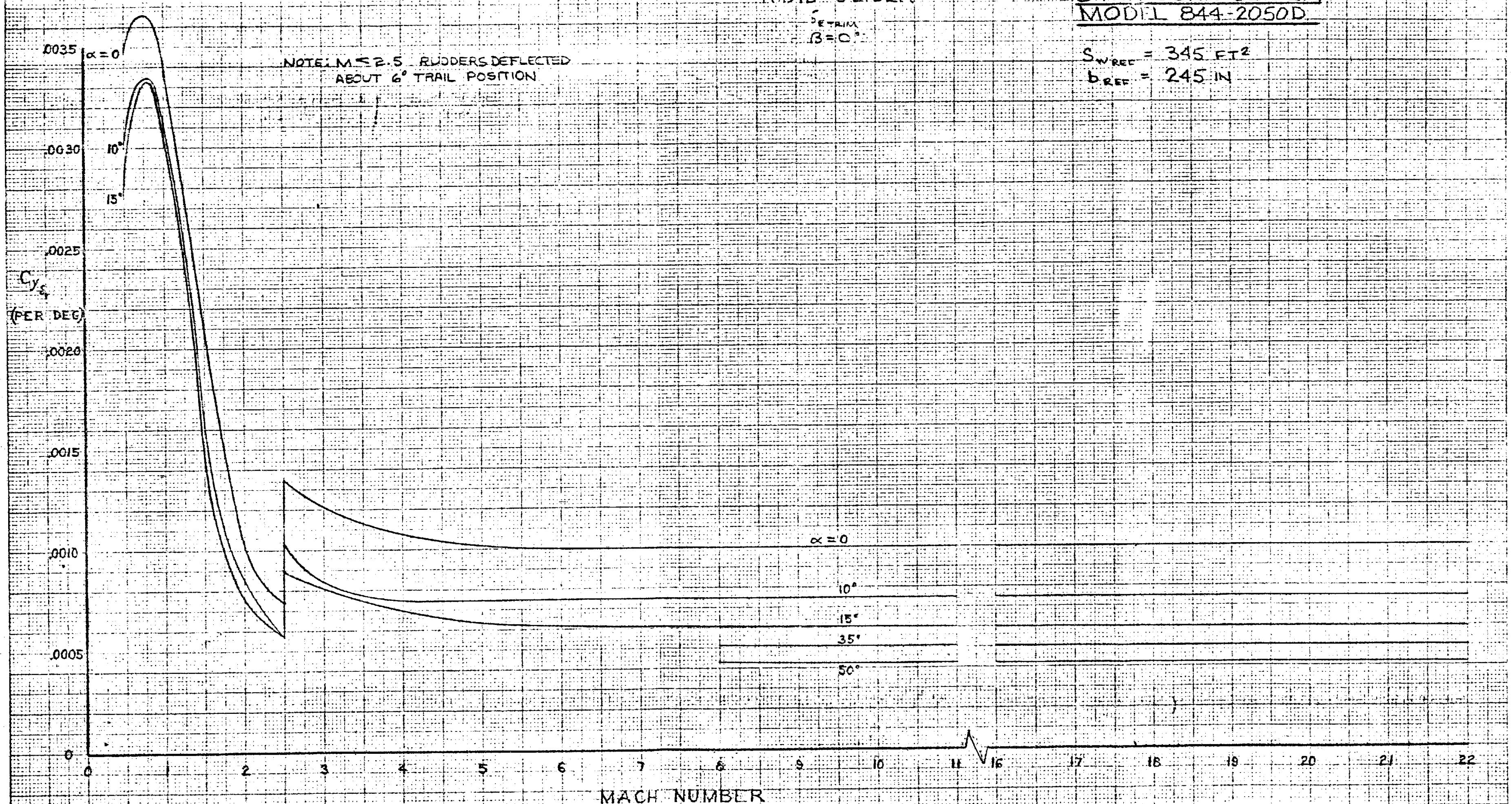

FIG. 6.95

CALC	PVT/EMP	REVISED	DATE	RUDDER EFFECTIVENESS ~ SIDE FORCE DERIVATIVE	844 — 2050 D
CHECK		12-26-1			D2-6000-5
APPD					PAGE 6.106
APPD					

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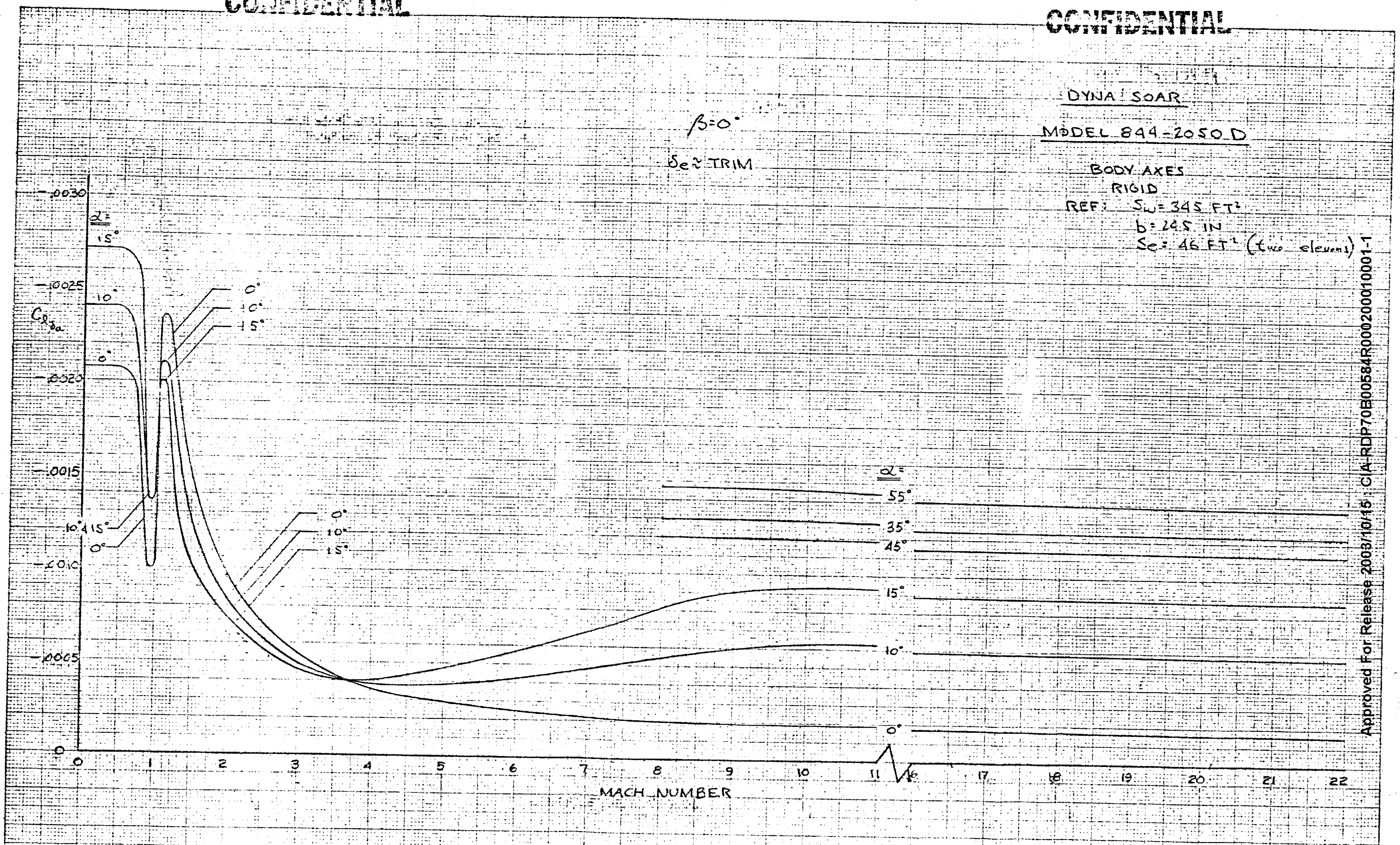

CALC	EJRI/JGF	11/13/1	REVISED	DATE
CHECK			12-2-1	
APPD				
APPD				

AILERON EFFECTIVENESS
ROLLING MOMENT

FIG. 6.96
844-2050D
D2-80065
PAGE 6.107

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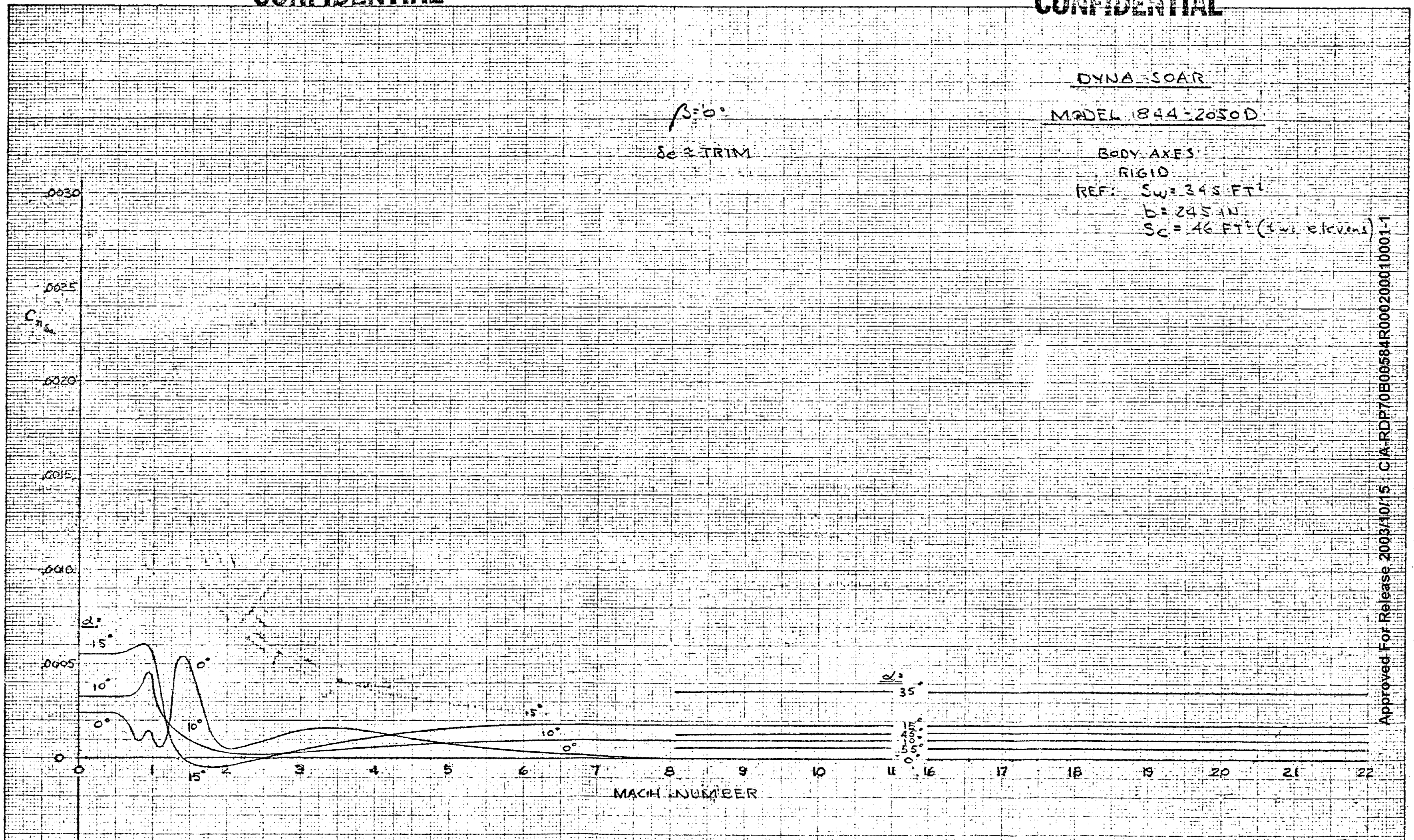

FIG. 6.97

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APPD						PAGE 6.108
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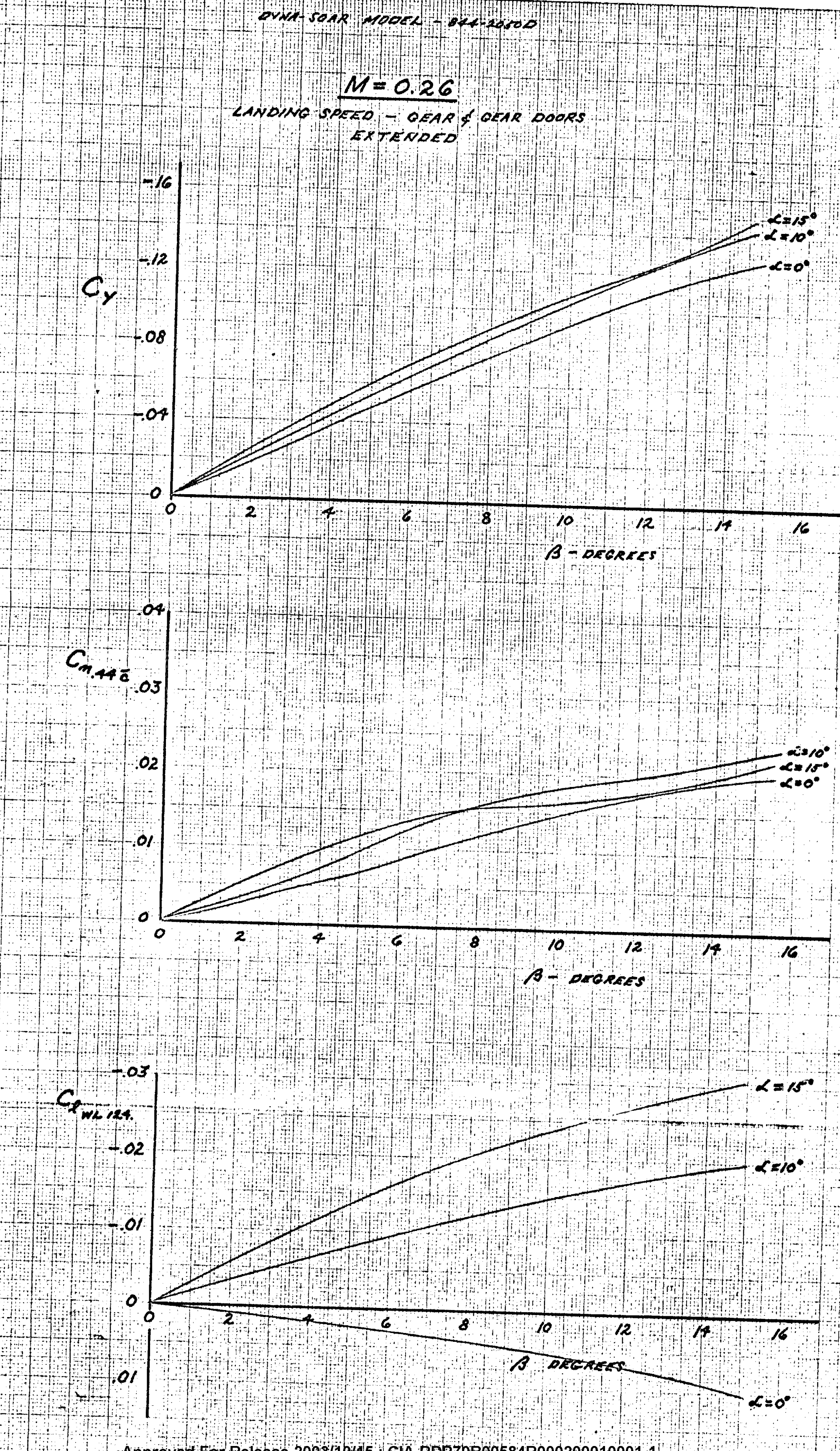
6.2.1 LANDING SPEED - GEAR AND GEAR DOORS EXTENDED

The stability characteristics as shown on Figure 6.98 are based on wind tunnel data for gear only from test BTWT 634, on glider data from test BTWT 682 and BTWT 685 and on calculation for gear doors extended for the 844-2050 D rigid glider. Test data for the complete built up configuration of 844-2050 D glider with gear and gear doors extended will be obtained in the near future.

Aileron characteristics and rudder effectiveness will be covered under Lateral Directional Subsonic and Transonic Speed 6.2.2.



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LATERIAL-DIRECTIONAL STABILITY
LANDING GEAR & GEAR DOORS
EXTENDED

FIG. 6.98
844-2050D
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6.2.2 SUBSONIC-TRANSONIC SPEED

Presented in this section are lateral directional stability, rudder effectiveness and aileron characteristics for the 844-2050 Revision D glider through the subsonic-transonic speed range.

Glider stability is shown in plots of C_n, C_y and C_l vs β in figures 6.99 through 6.103 at Mach numbers of .50, .90, .95, 1.0 and 1.10 for an elevon deflection of -10°. These data are based on Boeing transonic wind tunnel test 685 and modified for the Revision D configuration.

Figures 6.104 through 6.108 present rudder effectiveness for an elevon deflection of -10° at Mach numbers of .50, .80, .90, .95 and 1.10. The data are shown as C_n, C_y and C_l vs δ_r and are based on Boeing transonic tests 672 and 682. Dual rudder characteristics are shown in figures 6.104 through 6.108 and are representative of normal in-flight rudder operation. Figures 6.109 through 6.113 present the single rudder characteristics upon which the dual rudder data is based. The single rudder data may be used to determine rudder effectiveness at any initial rudder angle.

Aileron characteristics, C_n, C_y and C_l vs δ_a are shown in figures 6.114 through 6.117 for Mach numbers of .50, .80, .95 and 1.10. These data represent elevon deflections of -10° to -15° and are based on Boeing transonic test 672.

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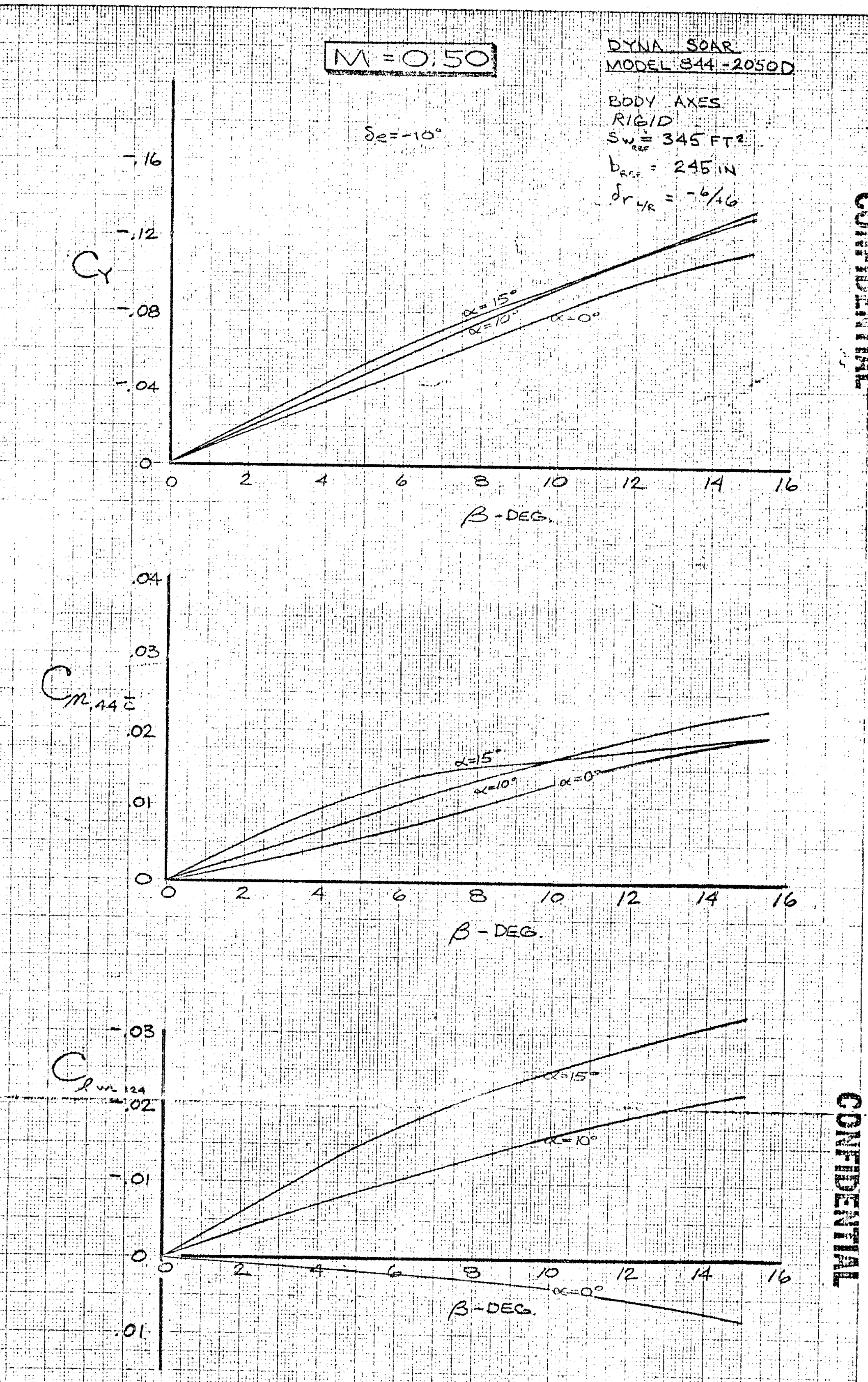

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LATERAL-DIRECTIONAL STABILITY
M = 0.50

FIG. 6.99
844-2050D
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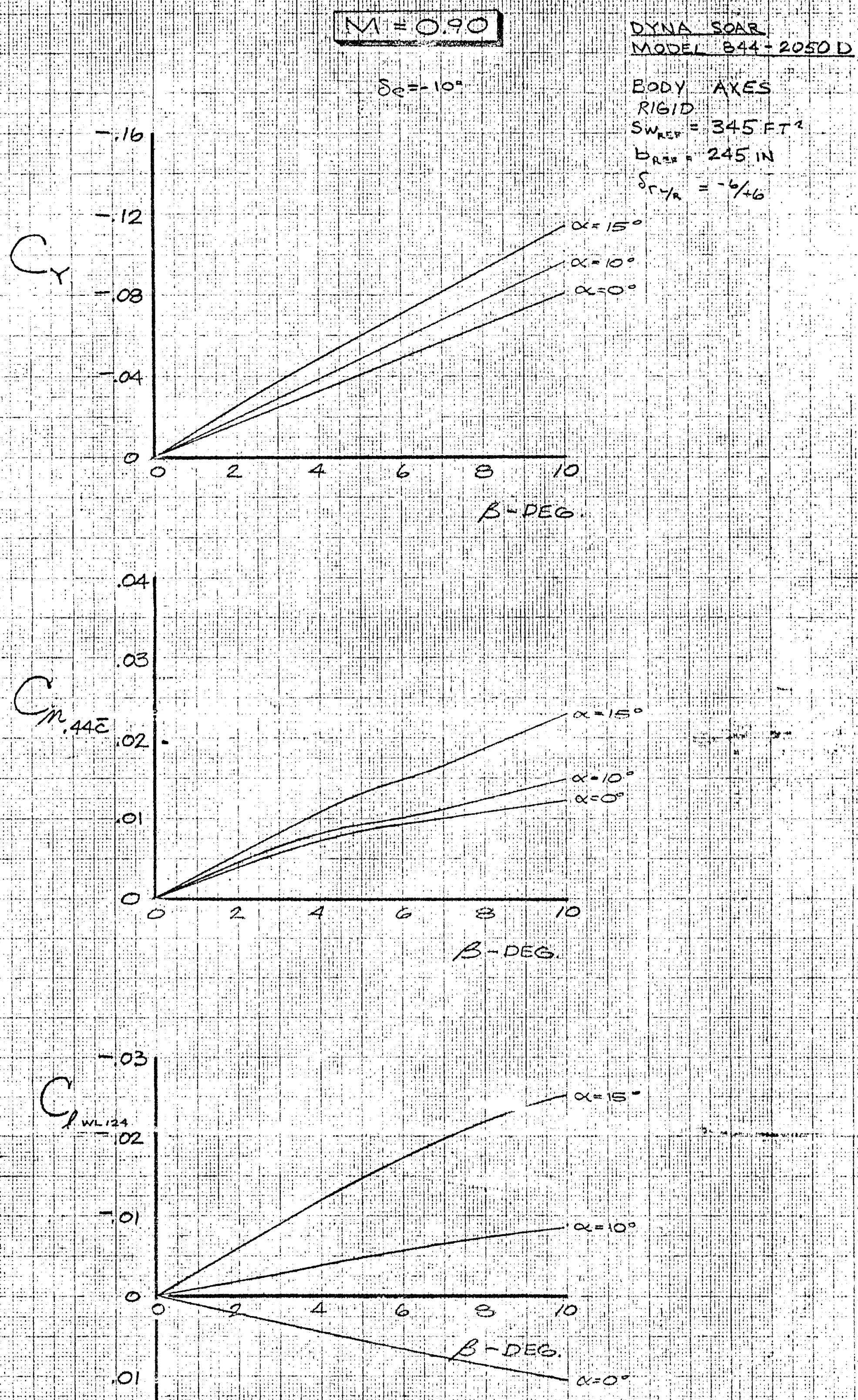

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LATERAL-DIRECTIONAL STABILITY
M = 0.90

FIG. 6.100

844-2050D

D2-80065

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